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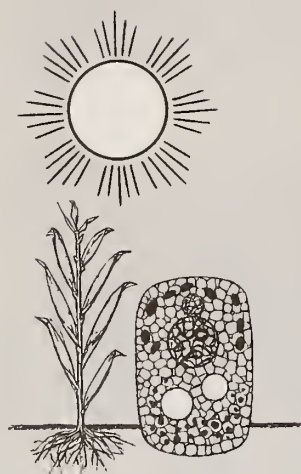
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End of an Era



AGRICULTURAL SCIENCE REVIEW

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Publication of this issue of *Agricultural Science Review* marks the end of an era; it is the last number of the journal which the Cooperative State Research Service will issue.

Because *Review* has attained a rather favorable standing as a science journal—not only among agricultural scientists themselves, but also among journalists—a bit of explanation is obviously in order. Basically, the reason for the discontinuance of *Review* is one of economics. Publications costs have risen to the point where we can no longer justify the luxury of a quality publication going to a limited audience strictly within the official circles of State-Federal research leaders. Instead, emphasis is being placed on the use of information funds in a manner that will carry the success stories of agricultural science directly to the public at large.

None of our readers—nor the members of our editorial board—would deny the continued need for a forum where qualified scientists can critically review and evaluate a given area of a science discipline. Steps are being taken to fill this need in a more economical fashion.

The history of this agency, particularly during the years when it was known as the Office of Experiment Stations (OES), carries the records of previous decisions to discontinue journals that had achieved high standings.

The *Experiment Station Record*, which began in 1889, served a useful purpose for 57 years until the scope of State experiment station research became so vast that OES could no longer cope with publishing the results of it. Likewise, the *Journal of Agricultural Research*, 1913–46, filled a useful niche until its role was taken over by the growing number of discipline journals. For what it is worth, therefore, the combined total span of journal publication sponsored by this agency figures out to a neat 100 years of communication service to the agricultural sciences.

The editorial staff, the editorial board, and all of CSRS take this occasion to express gratitude to both readers and contributors for their support of a journal that, we hope, will not soon be forgotten.—R. L. L.

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THE FIRST CENTENNIAL

A Hundred Years of Progress of American Agriculture

CHARLES L. FLINT

ONE hundred years ago, the Nation was preparing to celebrate its first centennial. Leading agriculturists were not allowing the occasion to slip by unnoticed without calling attention to the many advances in agriculture since 1776 and to the important role agriculture was assuming in the economy of the country.

Perhaps the most complete and thorough agricultural report ever prepared for the first centennial never really received the national attention it deserved. Instead, it appeared as a rather obscure

report of the secretary of the Massachusetts Board of Agriculture and was read to the members of that august body at its annual meeting in 1873. The author, Charles L. Flint, first secretary of the board and later president of the Massachusetts Agricultural College, sadly noted in his opening remarks that the report had been prepared at the request of the U.S. Commissioner of Agriculture for his last report, but that Congress had refused to publish the report. Hence, he and the board members settled

for having it read at the Massachusetts Board meeting.

Review is indebted to Arless A. Spielman, director, Massachusetts Agricultural Experiment Station, for providing a copy of this most interesting and valuable historical document. The article has particular significance to readers interested in comparing the agricultural advances of the first 100 years with those of the second. Moreover, it is a fitting prelude to the upcoming observance of the Nation's Bicentennial in 1976.

Mr. Chairman and Gentlemen:—The paper which I am about to present to you was written with the design of exciting some interest in the minds of the farming community as a preparation for the Centennial of 1876. It was prepared at the request of the Commissioner of Agriculture at Washington for his last Report, but as Congress refused to publish the Report, there appears little probability that it will be generally accessible to the people in that form, and hence several members of the Board have requested that it be submitted at this meeting.

The Centennial Celebration, to take place in the city of Philadelphia in the year 1876, is to be a memorial of the struggles, the sacrifices, the heroic endurance, and the triumphs of our fathers in founding a free government, claimed to be the highest type of civil polity which the world has ever seen. As the time draws nigh, this grand occasion appeals to the pride, to the patriotism, to the reverence for the past, to the memory of the dead, to the highest and most unselfish feelings of every American heart, to make it a success and, beyond all question, the grandest event of the sort which mankind has ever beheld. Anything short of this will fail of its purpose.

Before the Revolution

THERE is little need to look beyond the period of the Revolution in search of the first steps at any real progress in the agriculture of this country. The first European settlers upon these shores had to begin life anew, as it were, in the midst of untold

hardships, privations, and dangers. They found a climate widely different from any which they had known before; a soil which the foot of civilized man had never trod, and natural productions which they had never seen. They brought with them little or no experience which could have fitted them for the rude struggle with nature in which they were about to engage. This they were forced to gain, painfully and laboriously enough, with the axe in hand to clear the forest, and the gun by their side to defend their lives. That progress in agriculture should have been slow is not, therefore, a matter of surprise. We must rather wonder that they got on at all in the struggle for life.

The different colonies, no doubt, had a somewhat different experience. The winters of Virginia were milder than those of New England, and the settlers on the James River suffered less from this cause than those farther north, but all were alike surrounded by a wilderness infested by savage men and by wild beasts, always ready to prey upon their live stock or to destroy their crops. For some months after landing there were, indeed, no cattle to be destroyed. The first animals imported into the colonies were those that arrived at the James River plantation some time previous to 1609, the exact date of their arrival not being known. In 1610 several cows were landed there, and a hundred more in 1611. The first may have been brought by the early adventurers, either at the time of their first voyage, in 1607, or soon after, but the later additions probably came from the West Indies, being the descendants of the cattle brought to America, in his second voyage, by Columbus, in 1493.

So important was it considered that the cattle should be allowed to increase and multiply that, according to old authority, an order was passed forbidding the destruction of domestic animals, on pain of death to the principal, burning of the head and cropping of the ears of the accessory, and a sound whipping for the concealer of the facts. Such being the nature of the encouragement to the raising of stock, the number of cattle in the Virginia colony increased to about five hundred head in 1620, and to about thirty thousand in 1639, while the fact that the number had decreased to twenty thousand in 1648, would seem to indicate that the restriction had been removed. Many also had been sent to the colonies further north.

Although Mr. Flint's report has been slightly condensed, the editors of *Review* have not changed any aspect of the author's writing style, nor his manner of expressing ideas.

The wood cuts used to illustrate this article were originally published in the 1867 USDA Yearbook.

First Cattle in New England

THE first cattle that were brought to New England arrived at Plymouth in 1624, in the Ship Charity. They were imported for the colony by Gov. Winslow, and consisted of three heifers and a bull. They possessed no uniformity of color, being black and white, and brindle. In 1626 twelve cows were sent to Cape Ann, and in 1629 thirty more, while in 1630 about a hundred were imported for the "governor and company of the Massachusetts Bay in New England." In the meantime a hundred and three cattle and horses were imported into New York from the island of Texel, Holland, by the Dutch West India Company; and in 1627, the settlements along the Delaware were supplied by the Swedish West India Company, so that by the year 1630 the number of horned cattle in all the colonies must have risen, by importations and by natural increase, to several thousands, to which were added in 1631, 1632, and 1633, many yellow cattle from Denmark, brought over by Captain John Mason, who was engaged in extensive lumbering operations along the Piscataqua River, in New Hampshire.

These were the sources from which our common or "native" cattle sprang. The earlier importations were undoubtedly more extensive than any subsequent ones, the colonists relying upon the natural increase to supply their wants, but there is historical evidence to show that there was more or less interchange of stock between the various colonies at an early date, and that this resulted in a mixture of blood, such as we find it now in our common stock.

We are to bear in mind, also, that the stock of the mother country and of various countries from which the supplies of the colonists were drawn was not at that time improved as we find it in the present day. It was long before the interest in the improvement of stock had been awakened, and it is a historical fact that the ox of that day was small and ill-shaped, quite inferior to the ox of our own time; that the sheep has undergone a vast improvement, both in the fineness and value of its wool and the size and quality of the carcass, within the last century; that throughout the earlier part of the last century the average gross weight of the meat cattle sent to Smithfield market did not exceed three hundred and seventy pounds, and that of sheep twenty-eight pounds, while the average weight of the former is now over eight hundred pounds, and of the latter

over eighty pounds. Nor is it probable, on account of the high price of cattle at that period, and the risks to which they were exposed, that the colonists obtained the best specimens then known. In fact the difference in animals, and what are now considered the best points and the highest indications of improvement, were nowhere understood or appreciated two centuries ago. That the cattle of the early settlers were poor of their kind, as compared with our ideas of the quality of similar animals, is, therefore, plain enough to be understood.

Treatment of Cattle

IN addition to this, the means of keeping stock of any kind, in such a manner as to secure any improvement in it, were not at hand. The early colonists had no notion of raising grass or hay for their animals by artificial means. They relied chiefly, and almost from necessity, upon the production of natural meadows and the grasses upon the salt-marshes along the sea-shore. The cattle, like their owners, had to browse for their lives, and through the long northern winters to live upon poor and miserable swale-hay. Death from starvation and exposure was not uncommon, and sometimes an entire herd fell victims to the severity of the season. The most terrible droughts were of frequent occurrence, and caused great distress. The Indian corn and the grasses perished to such an extent that both grain and forage for stock, at times, had to be imported from England, to keep the people from starving, and to keep the cattle alive, even so late as 1750.

Of the mode of keeping cattle in the Virginia colony, Glover, a contemporary, as appears by the Historical Register, says: "All the inhabitants give their cattle in winter is only the husks of their Indian corn, unless it be some of them that have a little wheat straw, neither do they give them any more of these than will serve to keep them alive; by reason whereof they venture into the marshy grounds and swamps for food, where very many are lost." And Clayton, another contemporary authority, says that "they neither housed nor milked their cows in winter, *having a notion that it would kill them.*" A still later Swedish traveler, Kalm, after whom our beautiful mountain laurel, the *Kalmia*, was named, in speaking of the James River Colony, in 1749, says:

"They make scarce any manure for their corn-

fields, but when one piece of ground has been exhausted by continual cropping, they clear and cultivate another piece of fresh land, and when that is exhausted proceed to a third. Their cattle are allowed to wander through the woods and uncultivated grounds where they are half starved, having long ago extirpated all the annual grasses by cropping them too early in the spring, before they had time to form their flowers or to shed their seeds."

This statement will apply with nearly equal force to the other colonists of that date. That the description is strictly correct, I may quote from a distinguished Virginian, the Hon. James M. Garnett, who, in 1842, said:

"Previous to our Revolutionary war, as I have been told by the farmers of that day, no attempts worth mentioning were made to collect manure for general purposes, all that was deemed needful being saved for the gardens and tobacco-lots, by summer cow-pens. These were filled with cattle such as our modern breeders would hardly recognize as belonging to the bovine species. In those days they were so utterly neglected that it was quite common

for the multitude starved to death every winter to supply hides enough for shoeing the negroes on every farm. This was a matter so generally and constantly anticipated, that my own grandfather, as I have heard from unquestionable authority, was once very near turning off a good overseer because cattle enough had not died on the farm of which he had the supervision to furnish leather for the above purpose. When any cattle were fattened for beef, almost the only process was to turn them into the cornfields to feed themselves. Sheep and hogs were equally neglected."

Beginning of Grass Culture

IN order to realize still more fully the condition of the early settlers, so far as the treatment of their stock is concerned, we are to consider that no attention was paid to the culture of the grasses, even in England, in the early part of the seventeenth century, and that very few of the roots now extensively cultivated and used as food for stock had been introduced there. The introduction of red clover into



VICEROY AND EMPEROR 2a.

Cotswold Rams. Bred by ROBERT GARNE Aldsworth, Northleach, England, and imported and owned by BURDETT LOOMIS, Windsor Locks, Conn.

England did not take place till 1633; that of sainfoin, not till 1651; that of yellow clover, not till 1659; that of white or Dutch clover, not till 1700. Of the natural grasses, our well-known timothy was first brought into cultivation in this country, and it was not cultivated in England until the year 1760. The culture of orchard grass was first introduced into England from Virginia in 1764. There is no evidence of any systematic or artificial cultivation of grasses there until the introduction of the perennial rye grass in 1677, and no other variety of grass-seed appears to have been sown for many years; not, indeed, till toward the close of the last century, upon the introduction of timothy and orchard grass. The *Edinburgh Quarterly Journal of Agriculture*, the highest authority in such matters, says the practice of sowing grass-seed was never known in Scotland previous to the year 1792. Such being the case, in a climate so severe as that of Scotland, it is not at all surprising that the custom in this country dates back only little more than a hundred years.

It is a somewhat curious fact that the modern improvements in cattle in England did not begin till after the systematic culture of the higher qualities of natural grass. It is not strange, therefore, that the colonists here, who had vastly greater hardships to encounter in the practical operations of the farm, were slow to recognize the possibilities of improvement, or that their cattle, poor as they must have been at the outset, continued rather to depreciate than to improve in quality until sometime after the Revolution. The number increased, however, as the range of pasturage or browsing grounds was comparatively unlimited, so that the keeping of stock may be said to have assumed some importance in the older settlements, by the middle of the last century, when it had become comparatively safe from molestation.

Early Farm Implements

ONE of the chief obstacles the early colonists had to encounter, to add to the hardships of their lot in the cultivation of the soil, was the difficulty of procuring suitable implements. A few, no doubt, were brought with them, but all would not obtain them in this way, and the only metal they had was made of bog-ore, and that was so brittle as to break easily and put a stop to their day's work. Most of their tools were made of wood, rude enough in con-

struction, and heavy of necessity, and little fit for the purpose for which they were made. The process of casting steel was then unknown. It was discovered in Sheffield, England, but not till the middle of the last century, and then kept a secret there for some years. The few rude farming tools they had were for the most part of home manufacture, or made by the neighboring blacksmith as a part of his multifarious business, there being little idea of the division of labor, and no machinery by which any particular implement could be exactly duplicated.

The ploughs used by the French settlers upon the "American bottom," in Illinois, from the time of their occupation, in 1682, down to the war of 1812, were made of wood, with a small point of iron fastened upon the wood by strips of rawhide the beams resting upon an axle and small wooden wheels. They were drawn by oxen yoked by the horns, the yokes being straight and fastened to the horns by raw-leather straps, a pole extending back from the yoke to the axle. These ploughs were large and clumsy, and no small plough was in use among them to plough among corn till about the year 1815. They used carts that had not a particle of iron about them.

Most of the other implements of husbandry were very few and very crude. The thrashing was done with the flail. The winnowing was done by the wind. Slow and laborious hand-labor for nearly all the processes of the farm was the rule, and machine labor the exception, till a comparatively recent date. Indeed, it has been said that a strong man could have carried on his shoulders all the implements used on his farm, except, perhaps, the old wooden cart and the barrow, previous to the beginning of the present century, and we know that the number as well as the variety of these tools was extremely small.

Early Modes of Cultivation

OF the crops raised by the early settlers, and upon which they relied chiefly for sustenance, Indian corn, pumpkins, squashes, potatoes, and tobacco, were mostly new to them. Few Europeans had ever seen them cultivated previous to their arrival here but necessity soon showed their value, and from the Indians they learned how to grow them. It was a method followed with little change down to the opening of the present century. It was to dig small holes in the ground about four feet apart, put

in a fish or two, drop the seed, four or six kernels of corn, and cover it up. The instrument used by the Indians for this purpose was made of a large clam-shell, but the colonists soon substituted the heavy mattock or grub-hoe.

The James River settlers, under the tuition of the Indians, began to raise corn in 1608, and within three years after they appear to have had as many as thirty acres under cultivation. The Pilgrims found it under cultivation by the Indians on their arrival at Plymouth, and began its culture in 1621, manuring, as the Indians did, with alewives, then called "shads." In 1623 the drought was so severe and long protracted that the corn, planted very shallow and manured with these fish in the hill, soon began to wither and curl up, and on the higher lands it was ruined. And so in many years succeeding.

Wheat

WHEAT was first sown by Gosnold, on Cuttyhunk, one of the Elizabeth Islands, in Buzzard's Bay, as early as 1602, when he first explored the coast. In Virginia, the first wheat appears to have been sown in 1611, and its culture continued to increase there till, in 1648, it is recorded that there were several hundred acres of it. But it soon after fell into great dispute as a staple crop, as the tobacco culture was found to pay a great deal better. For more than a hundred years after it was but little cultivated in that colony. Wheat was early cultivated by the Dutch colony of the New Netherlands, for it is recorded that in 1626 samples of that grain were taken to Holland to show what could be done in the new country. It is probable that the Plymouth colony began its culture within two or three years of the settlement, though there appears to be no distinct record of it until 1629, when wheat and other grains for seed were ordered from England.

But though the cultivation of wheat was begun almost simultaneously with the settlement of the severed colonies, it did not attract very great attention for more than a century, Indian corn and, later, potatoes being relied upon for food to a much greater extent. It was soon found to be subject to blast and mildew in the eastern colonies.

The Potato

THE culture of the potato, though introduced early in the history of the colonies, being among the

seed ordered for the Plymouth Colony as early as 1629, was not recognized as a very important and indispensable crop till about the middle of the last century, when it had come to be widely known and esteemed as an article of food, for we know that in 1747 about seven hundred bushels were exported from South Carolina. It was the sweet potato that first came to be regarded as a delicacy in England, and the allusions of some rather early English writers undoubtedly refer to this, rather than the common potato.

Cultivation of Fruit

VERY little attention was paid to the raising of fruits previous to the Revolution, except for the manufacture of cider. The first apples were raised upon Governor's Island, in the harbor of Boston, from which, on the 10th of October, 1639, "ten fair pippens were brought, there being not one apple or pear tree planted in any part of the country but upon that island." The first nursery of young trees in this country was that planted by Governor Endicott on his farm at Salem, now Danvers, in 1640, and it is related that he sold five hundred apple-trees for two hundred and fifty acres of land. The systematic cultivation of fruit was not common in this country previous to the Revolution, nor did it become so till within the last fifty years. Orchards were set out upon many farms, but they were designed chiefly for cider. Much greater care, however, was taken to raise good fruits in New York, New Jersey, and Pennsylvania, than in New England, and several noted orchards and nurseries existed there in the latter part of the last century and the early part of the present, but they were the exception to the general rule even there. Choice varieties of apples, pears, peaches, and cherries were known only to a few careful cultivators, and the number of varieties of these was quite limited as compared with the present day. Cider was plenty, but its quality was much less regarded than its quantity. It is stated that so late as 1824 there was not a nursery for the sale of apple and pear trees in New England. Trees had to be bought in New York or New Jersey, or imported from abroad. The first horticultural society in the country was established in New York, about the year 1820. It lived but eight or ten years, and then died. The Pennsylvania

Horticultural Society was organized in 1827, and the Massachusetts in 1829. The orchard products, according to the last census, have now risen to \$48,000,000, and the general culture of fruit is rapidly progressing.

We are now prepared to appreciate the condition of our agriculture at the time of the outbreak of the Revolution. We have seen that the settlers had poor and inefficient tools, poor and profitless cattle, poor and meagre crops, and poor and miserable ideas of farming. They had no agricultural journals, no newspapers of any kind, and few books, except the old family Bible. There were less than a dozen papers published in the country at the middle of the last century. There was not one in New England at the beginning of that century, but four in 1750, and these had but a very limited circulation in the rural districts. There was little communication from town to town. The facilities for travel were extremely limited. It was before the days of many stages even, and the liberalizing influence which modern travel and social intercourse exert. Everything was favorable to the growth of prejudice and of narrow-minded views.

Restrictions on Colonial Agriculture

MOREOVER, it is to be considered that throughout all the days of the colonies, from the very outset, the policy of the home-government was to make the provinces a source of profit to the mother-country. It was a rigorous rule that all manufactured articles were to be procured of England. The colonies were not allowed to produce such articles for themselves, or to do anything which should come in conflict with the industry of the old country. But if there were any articles that England was in need of, the industry of the settlers was confined to them, and they could sell them only to England and buy what they required only of her. They encountered new restrictions at every turn. The grants or charters were issued, in some cases to individuals, in others to companies, and this involved, as it was clearly understood to involve, self-government; but the home-government very soon began to claim the right and the power of confirming the several governors. Some of the colonies were forbidden even to cut down pine trees suitable for ship timber, on any pretence. They were denied the right to export wool to any place out of the king's

dominions, to sell land to anybody except subjects of the British Crown, to ship any produce except in English vessels, to coin money, to do anything, in fact, which could lessen their dependence upon the mother-country.

Every new step taken, even in settling and working new lands, was met by some new and burdensome restraint, intended to keep the colonists in leading-strings. A formal act of Parliament, passed soon after the beginning of the last century, denied the right of the colonists to make hats. The home-government was very indignant at the custom which the people had of working up their wool and flax into homespun cloth. They were forbidden to manufacture ore beyond the state of pig-iron. Thus the most oppressive restrictions bore upon colonial agriculture, as well as upon colonial commerce and manufactures, from the very outset of the settlements. They finally became so burdensome as no longer to be endured with patience, and led to an open rupture with the home-government, commonly known as the Revolution, at a time when the population of the whole country was considerably less than three millions, the general and popular estimate of three millions being supposed to be too high.

During the period of the Revolution farm production was brought to a partial stand-still, and, for some years after, it was in a state of extreme depression. It took time to recover from the effects of the struggle. Gradually, however, the importance of some effort to develop and improve the agriculture of the country was impressed upon the minds of the more intelligent and public-spirited of the people, men, for the most part, who were in advance of their time. The result of their deliberations was the formation of societies for the encouragement of agricultural improvement.

Organized Effort

THE South Carolina Agricultural Society was established in 1784; the Philadelphia Society for Promoting Agriculture, in 1785; the New York (city) Society, in 1791; the Massachusetts Society for Promoting Agriculture, in 1792. These were city rather than country institutions. They were very slow in reaching the common people. The average farmer of that day was not up to their standard of thought and observation. Their example, their teachings, their entreaties for aid, their reports and

papers, fell comparatively dead upon the mass of the people. Farmers were not to be taught by men who never held the plough. They did not want anything to do with *theories*. Custom had marked out a road for them, and it was smooth and easy to travel, and, though it might be a circle that brought up just where it had started, it had the advantage, in the old farmer's mind, that in it he never lost his way. It didn't require any exertion of mind. His comfort, as well as his happiness, was based on a feeling of filial obedience to old usage that was hereditary in his being. It was born in the blood, and ruled him with an irresistible power. His field of vision was bounded and narrow, and his work was strictly *imitative*, so far as he could see, and in no way *experimental*.

To investigate would imply doubt. To investigate was to theorize. Theory is at the bottom of all investigation, and theory was a bugbear in his mind. The logical result—that no improvement could be reached without investigation—had no terrors for him. He seldom read. The *written* word he received with distrust. It might contain principles, and it wasn't principles that he cared anything about, but *practice*. No matter whether founded on wisdom and experience or not, practice was the thing. It seemed to be his opinion that farming could not be improved though it might be injured by books. Its processes were so peculiar that they could be gained only by tradition.

Public Exhibitions

BUT time brings its changes. Something more was felt to be needed, and a convention was held in Georgetown, in the District of Columbia, on the 28th of November, 1809, from which grew the Columbian Agricultural Society for the Promotion of Rural and Domestic Economy; and the first exhibition, probably, in this country, was held by that society on the 10th of May, 1810, with the offer of liberal premiums for the encouragement of sheep-raising, etc. Elkanah Watson exhibited three merino sheep in Pittsfield, Massachusetts, in the October following of the same year. It was an innovation upon old custom, and the occasion of much ridicule and contempt among the farmers of that day and generation, but it was the germ of the Berkshire County Agricultural Society, whose regular exhibitions began the year following, and are believed to

have been the first county exhibitions ever instituted in this country.

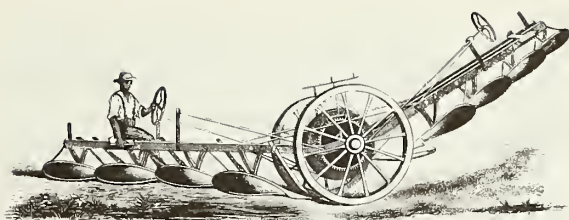
The Massachusetts Society held its first exhibition at Brighton in 1816, offered a list of premiums, and instituted a ploughing match; but it appears to have been rather with the design of testing the strength, training, and docility of the oxen than to improve the plough. The plough-maker, however, happened to be there with his eyes open, and there can be no doubt that this and similar exhibitions which soon followed gave a new impetus to the progress of agricultural mechanics.

Cast-Iron Used

IMPROVEMENTS in the plough had begun, even before the close of the last century. A patent had been granted for a cast-iron plough to Charles Newbold, of Burlington, New Jersey, in 1797, combining the mould-board, share, and land-side, all cast together, and it was regarded by intelligent plough-makers as so great an improvement that Peacock, in his patent of 1807, paid the original inventor the sum of \$500 for the right to combine certain parts of Newbold's plough with his own. The importance of this implement was so great as to command the attention and study of scientific men to improve its form and construction, and Thomas Jefferson, in 1798, applied himself to the task, and wrote a treatise upon the requisite form of the mould-board, according to scientific principles, calculating the exact form and size, and especially the curvature to lessen the friction. I have in my possession his original manuscript of this essay, containing his drawings and calculations.

But these changes and improvements were not readily adopted by the farming community. Their introduction was far slower than any new invention that promised to economize labor and do better work would be at the present day. Many a farmer clung to his old wooden plough, asserting that cast-iron poisoned the ground and spoiled the crops. He required a demonstration before paying his money for an iron plough.

The modifications of the mould-board, which resulted from a better understanding of the true principles of construction, have enabled the farmer to do vastly better work, and a greater amount of it in the same time, and at a less expenditure of strength,



FOWLER'S BALANCE STEAM PLOUGH.

and to reap larger crops as the result of his labor, while the cost of the implement, considering its greater efficiency and its durability, is less by half, probably, than the old wooden plough.

The Crowning Glory

BUT perhaps the most important of modern agricultural inventions are the grain-harvesters, the reapers, the mowers, the threshers and the horse-rakes. The sickle, which was in almost universal use till within a very recent date, is undoubtedly one of the most ancient of all our farming implements. Reaping by the use of it was always slow and laborious, while from the fact that many of our grains would ripen at the same time, there was a liability to loss before they could be gathered, and practically there was a vastly greater loss from this cause than there is at the present time.

It is not, therefore, too much to say that the successful introduction of the reaper into the grain-fields of this country has added many millions of dollars to the value of our annual harvests, by enabling us to secure the whole product, and by making it possible for the farmer to increase the area of his wheat-fields, with a certainty of being able to gather the crop.

Nothing was more surprising to the mercantile community of Europe than the fact that we could continue to export such vast quantities of wheat and other breadstuffs through the midst of the late rebellion, with a million or two of able-bodied men in arms. The secret of it was the general use of farm-machinery. The number of two-horse reapers in operation throughout the country, in the harvest of 1861, performed an amount of work equal to about a million of men. The result was that our capacity for farm production was not materially disturbed.

The credit of the practical application of the principles involved in this class of machines undoubtedly belongs to our own ingenious mechanics; for though

somewhat similar machines were invented in England and Scotland many years ago, they had never been proved to be efficient on the field, and had never gained the confidence of the farmers, even in their neighborhood; while the patent issued to Obed Hussey, of Cincinnati, in 1833, and another issued to McCormick, of Virginia, in 1834, not only succeeded in the trials to which they were subjected but gained a wide and permanent reputation. Many patents had been issued in this country previously, the first having been as early as 1803, but they had not proved successful. Hussey's machine was introduced into New York and Illinois in 1834, into Missouri in 1835, into Pennsylvania in 1837, and in the next year the inventor established himself in Baltimore. McCormick's machine had been worked as early as 1831, but it was afterwards greatly improved, and became a source of an immense fortune to the inventor. He took out a second patent in 1845, fifteen other machines having been patented after the date of his first papers, including that of the Ketchum, in 1844, which gained a wide reputation.

National Trials

THE first trial of reapers, partaking of a national character, was held under the auspices of the Ohio State Board of Agriculture in 1852, when twelve different machines and several different mowers were entered for competition. There was no striking superiority, according to the report of the judges, in any of the machines. A trial had been held at the show of the New York State Agricultural Society, at Buffalo, in 1848, but the large body of farmers who had witnessed it were not prepared to admit that the work of the machines was good enough to be tolerated in comparison with the hand-scythe. Some thought they might possibly work in straight, coarse grass, but in finer grasses they were sure to clog. The same society instituted a trial of reapers and mowers at Geneva in 1852, when nine machines competed as reapers and seven as mowers. Only two or three of the latter were capable of equalling the common scythe in the quality of work they did, and not one of them all, when brought to a stand in the grass, could start again without backing to get up speed. All the machines had a heavy side-draught, some of them to such an extent as to wear seriously on the team. None of them could turn

about readily within a reasonable space, and all were liable to tear up the sward in the operation. The old Manning, patented in 1831, and the Ketchum machines were the only ones that were capable of doing work that was at all satisfactory. One or two of the reapers in the trial did fair work, and the judges decided that, in competition with the hand-cradle, they showed a saving of $88\frac{3}{4}$ cents per acre. Here was some gain certainly, a little positive advance, but still most of the reapers, as well as the mowers, did very inferior work. The draught in them all was very heavy, while some of the best of them had a side-draught that was destructive to the team.

Before the World

THE inventive genius of the country was stimulated by these trials to an extraordinary degree of activity. Patents began to multiply rapidly. Local trials took place every year in various parts of the country to test the merits of the several machines. The great International Exposition at Paris in 1855 was an occasion not to be overlooked by an enterprising inventor, and the American machines, imperfect as they were at that time, were brought to trial there in competition with the world. The scene of this trial was on a field of oats about forty miles from Paris, each machine having about an acre to cut. Three machines were entered for the first trial, one American, one English, and a third from Algiers, all at the same time raking as well as cutting. The American machine did its work in twenty-two minutes, the English in sixty-six, and the Algerian in seventy-two.

At a subsequent trial on the same piece, three other machines were entered, of American, English, and French manufacture, when the American machine did its work in twenty-two minutes, while the two others failed. "The successful competitor on this occasion," says a French journal, "did its work in the most exquisite manner, not leaving a single stalk ungathered, and it discharged the grain in the most perfect shape, as if placed by hand for the binders. It finished its piece most gloriously." The contest was finally narrowed down to three machines, all American. Two machines were afterwards converted from reapers into mowers, one making the change in one minute, the other in twenty. Both performed their task to the astonish-

ment and satisfaction of a large concourse of spectators, and the judges could hardly restrain their enthusiasm, but cried out "Good, good!" "Well done!" while the excited people who looked on hurrahed for the American reaper, crying out, "That's the machine!" The report of a French agricultural journal said: "All the laurels, we are free to confess, have been gloriously won by Americans, and this achievement cannot be looked upon with indifference, as it plainly foreshadows the ultimate destiny of the New World."

Every year now added to the list of new inventions and improvements. In 1859 the Wood mower was invented, and soon gained a high reputation. By 1864 there were no less than a hundred and eighty-seven establishments in the country devoted to the manufacture of reapers and mowers, many of them very extensive, and completely furnished with abundant power, machinery and tools of the most perfect description, while the work had become wisely and thoroughly systematized. The people directly sustained by these factories exceeded sixty thousand, while the value of their annual product exceeded \$15,000,000, the number of machines amounting to one hundred thousand.

Making and Gathering Hay

THE horse hay-rake was invented at an earlier date than the mowing-machine. It has been used in this country nearly seventy years, and the saving by its use, sixty years ago, was estimated to be the labor of six men in the same time. The work to be performed in raking hay, though slow, is comparatively light. It does not require the exertion of a very great amount of strength. It is just such kind of work where the application of animal power becomes of the greatest advantage, because it multiplies the efficiency of the hand many times. The same thing is noticed in the use of the hand-drills for sowing small seeds, the tedder for turning and spreading hay, and in other similar operations. The labor of a good horse-rake is equal to that of eight or ten men for the same time, and from twenty to thirty acres a day can be gathered by a single horse and driver, and that without over-exertion. In the economy of labor the horse-rake must be regarded as second only in importance to the mower and the reaper, and is considered as essential upon the farm as the plough itself.

Grain Separators

WHILE these vast improvements have been going on with the other implements of the farm, the improvement in machines for threshing grain has been rapidly progressing, till they have reached a wonderful degree of perfection. Most of us can remember when the old-fashioned flail was heard upon almost every barn floor in the country. Here and there was a case where the grain was trodden out by cattle, with amazing waste of time and labor. Compare those slow methods with the process, widely known at the present day, by which a horsepower or steam-power thresher not only separates the grain but winnows it, measures it, bags it ready for market, and carries away the straw to the stack, at the same operation, and all with a rapidity truly astonishing. The first successful attempt to construct a threshing-machine was made in this country in 1792, by Col. Anderson of Philadelphia. It answered the purpose well, but the inventor did not follow it up so as to secure its general introduction. Other patents were subsequently issued to American inventors, but they were not successful in introducing them. Scotch machines were introduced into New York, Pennsylvania, and Delaware in 1802, but they were too complicated and were soon laid aside. An English machine was introduced in 1816 that proved a success in respect to speed and ease of cleaning grain, and portability, but subsequent inventions have so far surpassed all these comparatively early attempts, that they have superseded them, and later American machines have been used for many years.

As early as the Paris Exposition of 1855 the victory was won by an American machine. To ascertain the comparative rapidity and economy of threshing, six men were set to work at threshing with flails. In one hour they threshed 36 litres of wheat. In the same time Pitt's American machine threshed 740 litres; Clayton's English machine threshed 410 litres; Duvoir's French machine threshed 250 litres; Pinet's French machine threshed 150 litres.

Other Implements

NOR has the progress in the improvement of other indispensable machines of the farm been less marked and important. The smaller implements

have felt the impress of the mechanical genius of the age.

Patents issued for improvements in agricultural implements and machinery for the year 1872 exceeded one thousand, of which thirty-six were for rakes, one hundred and sixty for hay and grain harvesters and attachments, one hundred and seventy-seven for seed planters and drills, thirty for hay and straw cutters, ninety for cultivators, seventy-three for bee-hives, ninety for churns, and one hundred and sixty for ploughs and attachments; and that the annual manufacture of agricultural implements amounts to over \$52,000,000.

The King of Cereals

INDIAN corn has always been regarded as the great staple crop of the country. It is a plant of American origin, and it soon became the leading crop throughout the country, the crop upon which the colonists relied, not only for food, but for sale and exchange for other necessities of life. It soon became a prominent article of export, especially from the Middle States—New Jersey, Pennsylvania, and Delaware—and, to some extent, from the States farther south. Thus, in 1748, South Carolina exported 39,308 bushels, and in 1754, 16,428 bushels. In 1755, there were exported from Savannah 600, and in 1770, 13,598 bushels. And so, in 1753, North Carolina exported 61,580 bushels; and the exports from Virginia, before the Revolution, sometimes amounted to 600,000 bushels a year. The total amount exported from all the colonies, in 1770, was 578,349 bushels. These figures are not large, to be sure, when compared with the immense exportation of this grain at the present day, but they serve to show that, even before the Revolution, Indian corn had come to be regarded as an important money crop, as well as a prime necessity for home consumption. They show a surplus beyond the wants of the population at that time.

This wonderful rapidity of increase continued, partly on account of the vast improvement in agricultural implements and the means of raising the crop, partly on account of the multiplicity of railroads and market facilities, till, in 1860, it amounted to 838,792,742 bushels; but it had fallen off somewhat in 1870, for it is reported then as 760,944,549 bushels, a portion of the land evidently having been devoted to wheat, which had very largely increased

in the same time. When it is considered that our agricultural resources are still but partially developed, the product of this cereal appears to be truly amazing.

Wheat Culture

NOR is the growth of wheat in this country less important than that of Indian corn. In some respects it is even more so. It is the brain-food of the world. It has been said that the progress of civilization and intellectual culture can be traced from one degree to another by the extent of its growth and consumption. It is gratifying, therefore, to find that our present annual production of this cereal amounts to nearly 300,000,000 bushels, and that our ability to increase it is capable of an almost unlimited expansion. It has always entered into our exports to an extent dependent chiefly upon the foreign demand, and experience has proved that the surplus of this grain, the amount we could spare from home consumption, is as elastic as Indian-rubber. If Europe needs our wheat or our flour, and is ready to pay us good prices, either from a short crop, a disturbed state of political affairs, or from any other cause, no one could set bounds to our surplus, because the more she wants the more we have to spare, and the less she requires, the more freely is it used at home. In other words, the amount of exports will be regulated chiefly by the price, and if foreign countries are willing, or are compelled to pay for it, we can supply them to any extent under any ordinary circumstances. The export, for instance, in 1850, amounted to little more than eight millions and a half, while in 1854 it went up to over twenty-seven millions of bushels.

We have seen that wheat was cultivated, to some extent, by the early settlers of the country. Occasionally, to meet the exigency of a short crop in England, France, Portugal, Spain, or the West Indies, it was exported, to some extent, in the early part of the last century. By the year 1750, New Jersey had come to take the lead of all the Colonies in raising wheat, and may be regarded as at that time the great centre of the wheat-growing region. Its culture had grown to be very considerable along the Hudson and Mohawk, and in Pennsylvania. Maryland, Virginia, and the provinces further south had made tobacco the leading object of culture, almost from the first of their settlement, and this

crop constituted for a long time the most important export from the British provinces, though North Carolina had shipped, on an average, about 130,000 barrels of pitch, tar and turpentine, and South Carolina considerable quantities of rice. But the product of tobacco had been diminishing for some years previous to the Revolution, on account of the exhaustion of the soil for that crop, and the planters there had turned their attention, to a greater extent, to the growing of wheat and other grain. They could by law export tobacco only to Great Britain, but they could ship wheat, flour, lumber, etc., to the West Indies and elsewhere. Wheat, therefore, had begun to enter into the exports of the more southern provinces prior to the Revolution.

Increase of Production

BUT that the production of wheat and flour had not risen to anything like the relative importance which it holds at the present time, will appear from the fact that in 1791 the export of this grain was but 1,018,339 bushels, and 619,681 barrels of flour; while in 1800 it was but 26,853 bushels of wheat and 653,052 barrels of flour. In 1810 the amount sent abroad was 325,024 bushels of wheat and 798,431 barrels of flour. No statistics of actual production of this grain were gathered previous to the census of 1840, but it is reported in that year to have been 84,823,272 bushels. From that time to 1850 the increase appears to have been but 15 percent, the product, at the latter date, being 100,485,944. In that year, or rather in 1849, on which the return is based, Pennsylvania produced more than any other State in the Union, or 15,367,691 bushels. Its product at the last census was nearly 20,000,000, but the centre of production has moved farther to the west.

Since the practicability and economy of the reaper and other machinery became certain, the increase in the production of wheat has been more rapid, as appears from the fact that in 1860 the crop amounted to 173,104,924 bushels, and in 1870 to 287,745,626 bushels. Our exports of this cereal in 1860 amounted to about 12,000,000 bushels, in 1861 to over 20,000,000, and in 1862 to very near 30,000,000, a greater quantity than had ever been known before. In addition to the vast increase of this crop in the Middle and Western States, the production of wheat in California now comes in to swell the aggregate capacity of expansion, to an extent worthy of notice; for while in 1850 her product of

wheat is returned as only 17,228 bushels, her yield of 1870 was nearly 17,000,000 bushels, with her resources but slightly developed. And when it is considered that the great Northwest,—Iowa, Minnesota, and the region lying beyond them,—still remains, to a large extent, unoccupied, there seems no reason to apprehend that the growth of this important crop will not continue to increase in the future as rapidly as it has in the past.

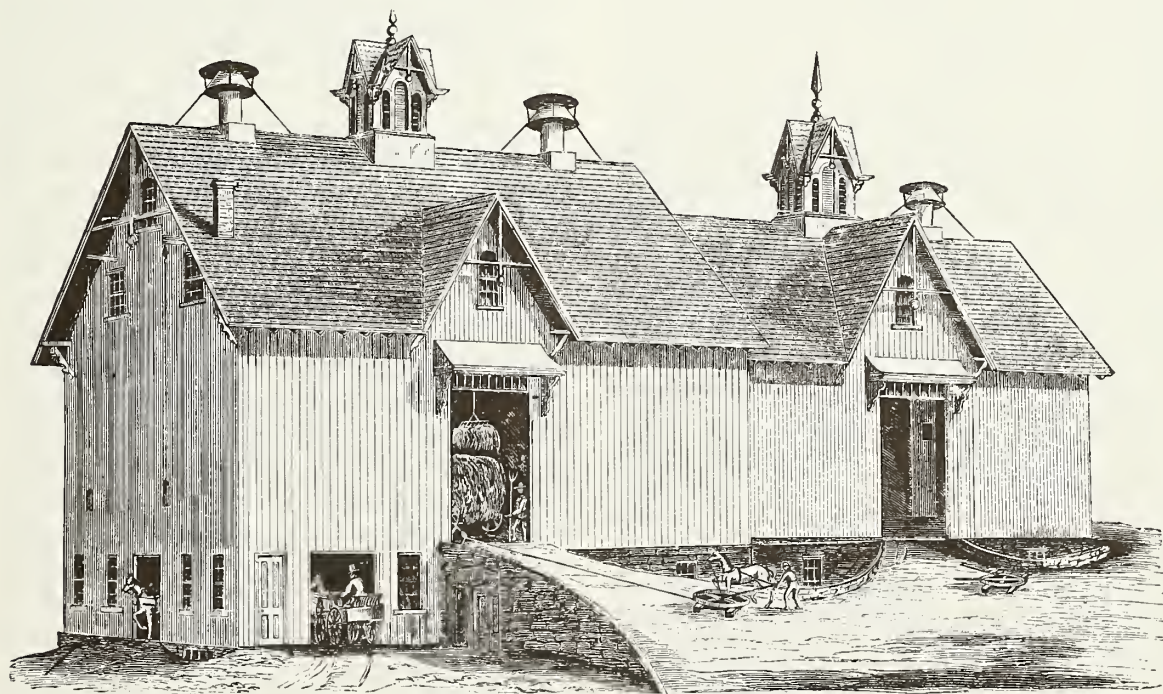
The other smaller grains have never occupied so prominent a position in our agriculture, being grown more especially for home consumption, but in the aggregate they constitute no mean item of our national agricultural wealth. Thus our rye-crop, as returned in 1870, amounted to nearly 17,000,000 bushels, our barley to nearly 30,000,000, our buckwheat to nearly 10,000,000, and our oats to over 282,000,000. Rice, which in 1860 was reported at 187,167,032 pounds, had fallen off in 1870 to 73,635,021 pounds.

An Early Export

THE culture of tobacco was undertaken by the settlers in Virginia from the very outset of the col-

ony. It is recorded that in 1615 the gardens, fields, and streets of Jamestown were planted with tobacco. It immediately became not only the great staple crop, but the principle currency of the colony. By the year 1622 the product amounted to 60,000 pounds, and it more than doubled in the next twenty years. The culture of this plant was introduced into the Dutch colony of New York in 1646, though it never gained the prominence there that it did farther south. But Maryland, the Carolinas, Louisiana, and later, Kentucky, made it the leading object of their culture almost from their first settlement. It long constituted the most valuable export of British America; but the product per acre had been diminishing for many years before the Revolution, owing to the difficulty of supplying manure, and the consequent exhaustion of the soil. But from 1744 to 1776 the exports of this crop averaged 40,000,000 pounds a year.

Tobacco has now become a somewhat prominent crop in Massachusetts and Connecticut, and in both of these States its culture is rapidly extending. In 1850, for instance, but 138,246 pounds were raised in Massachusetts; in 1860 the crop increased to



DAVID LYMAN'S BARN. (Northwest View.)

3,233,198 pounds, and in 1870 to 7,312,885, while the crop of 1872 is probably at least 25 percent greater still.

The Cotton Supply

THE cotton crop of the country has grown up entirely within the last hundred years. The first improvements in the process of spinning it in England were not made till the invention of Arkwright, in 1769, and the spinning-jenny in 1770, and comparatively little cotton had been raised in our Southern States previous to 1793, when Eli Whitney invented the cotton-gin. Up to that time the difficulty of freeing the cotton from the seed had been such that one hand could clean but a pound a day, and even at the high price of 25 or 30 cents a pound it could not be made profitable. By Whitney's invention a hand, instead of one pound, could clean 360 pounds a day.

The effect of machinery was to produce a vital change in the state of affairs at the South, and the cotton crop very rapidly grew up to immense importance, constituting about a third part of the whole exports of the country. Each decade gained an increase of about 100 percent in production, till, by 1874 it had reached 744,000,000 pounds, six times the product of 1820.

Improvement of Stock

THE present advanced position of the stock interest of this country can be traced directly to the practical labors of Bakewell, the Messrs. Cully, Colling, Bates and others, just as the first impetus which distinguished breeders received can be traced to the efforts of such men as Lord Kames, "to improve agriculture by subjecting it to the test of rational principles," and Jethro Tull (1740), the inventor of the horse-shoe, the drill-husbandry, and many other bold and advanced notions. Tull launched out bravely into the field of experimental agriculture, and boldly threw open the door of improvement never again to be closed, and this new-born spirit of progress very soon appeared to spread; for it was only about ten years after him, or about 1750, when Bakewell began those skillful experiments in breeding and with such marked success as to impress his influence upon the progress of agriculture all over the civilized world.

There were not many nor frequent importations of livestock until after 1820 though a herd of Devons, consisting of a bull and six heifers, presented to Robert Patterson of Baltimore, by Mr. Coke, afterwards Earl of Leicester, were imported in 1816; twelve head of Shorthorns arrived in Kentucky in 1817, and two more in 1818. It was in that year the celebrated bull Coelebs, the founder of Colonel Jaques's "cream-pot breed," Fortunatus, owned by Gorham Parsons of Brighton, and Young Denton, owned by S. Williams of Northborough, were imported into Massachusetts, while Henry Clay introduced the Herefords into Kentucky in the year 1817, and Colonel Saunders's importation of Shorthorns arrived in that State the same year.

Of all these early importations made by public-spirited individuals, the Patton stock probably made the most mark. They did much to teach people the possibility of improvement. They were the pioneers, and, together with subsequent importations, not only infused their blood into the stock of that great Western country, but did something to excite a spirit of emulation among the farmers there, and this may be said to have laid the foundation for the splendid results which Kentucky, Ohio and adjoining States have since realized.

After 1820, importations became more frequent. But though from time to time all the prominent breeds, the Shorthorns, the Herefords, the Devons, the Ayrshires, and the Jerseys, were introduced on trial and, to some extent crossed with our common cattle, the interest in stock was confined chiefly to individuals. The mass of farmers were slow to make changes, especially among the smaller farmers at the East. We may discover the first evidences of some general interest at the West about the year 1834, when the Ohio company for importing English cattle gave a great impetus to the spirit of improvement by large importations of Shorthorns, and from that date the progress in cattle-husbandry became very rapid, and we see the magnificent results of it at the present day. Early maturity and a tendency to fatten well are of transcendent importance to the Western farmer who breeds to supply the stalls in our Eastern markets, and he was quick to see how he could improve the intrinsic qualities of his stock in these respects.

In the Eastern portions of the country the dairy

early became the leading object of pursuit. Size and fattening properties were of less account, and hence we find that modern importations for that section have consisted chiefly of the celebrated dairy breeds, of which the Ayrshires and the Jerseys have taken the lead, according to the special object proposed.

While the constant introduction of improved cattle from abroad has effected a very marked general improvement in the quality of our animals, the universal interest in cattle-husbandry has led to greater knowledge of stock, to better systems of feeding and management, and so to more satisfactory results. No longer ago than 1841, Mr. Colman, a well-known agriculturist, remarked that the general treatment of cows at that time, in New England, would not be an inept subject of presentment by a grand jury. Now they are better sheltered, better fed, and more tenderly treated.

And while this progress in the improvement of the intrinsic qualities of our stock has been going on, the number of meat-cattle in the country has largely increased. The aggregate number by the census of 1840 was 14,971,586; in 1850 it was 18,378,907; while by the census of 1870 we find 23,820,608. Of these there were about 9,000,000 cows. It will be seen that the amount invested in this class of livestock alone cannot be less than \$300,000,000, the total value of the live-stock of the country being officially reported as \$1,525,276,457.

The Dairy Industry

IT would be interesting to study the form in which the product, or, in other words, the profit of the vast amount of capital invested in stock appears in different parts of the country. Space will admit of only a brief allusion to this point, but it is evident that throughout the Northern and Middle States it will appear very largely in the form of dairy products, while in the West we shall find it more generally in the form of slaughtered animals. Among the dairy products we find by the last census that we sold 235,500,599 gallons of milk in its natural form. It went chiefly to supply our large towns and cities; the figures not representing the vast amount consumed at home, and thus contributing so much to the comforts and the necessities of life. At the same time we produced 514,092,683 pounds of butter and 53,492,153 pounds of cheese.

These figures, large as they are, do not represent anything like the production of the country. The value of butter made in New York alone in the year 1865 exceeded \$60,000,000. It is quite within bounds to say that the butter product of the country is fully 600,000,000 pounds, and that the cheese exceeds 200,000,000 pounds a year.

The Packing Business

ANOTHER product of the cattle-husbandry of the country, and a most important one, whether considered from a financial point of view merely, or as furnishing a vast amount of food for the sustenance of mankind, is represented in the value of animals slaughtered or sold for slaughter, and by the census of 1870 we find this item amounts to about \$400,000,000, or more accurately, \$398,956,376, a gain in ten years of very nearly \$200,000,000. This, of course, includes the pork-packing business, till recently confined, to a large extent, to certain Western cities, but now carried on as a growing business at many convenient points along our great lines of railway in other parts of the country.

Improvement in swine began less than three-quarters of a century ago. The first that excited any general interest was made by some animals sent from Woburn Abbey, by the Duke of Bedford, to General Washington. The Englishman intrusted with the care of delivering them seized an opportunity to sell them on their arrival in this country, but they were bred and became popular, and from all accounts they were splendid animals, small and fine in the bone, with a deep round barrel, short in the leg, feeding easily, and maturing early. They were long known as the Woburn breed, and in some sections as the Bedford hog, and were originated by a fortunate cross of the Chinese and the large English hog of that day. They would weigh from four to seven hundred pounds at a year old, with light offal and most excellent quality of flesh. They became very common in Maryland, Delaware, and Virginia, and they were sent to Colonel Timothy Pickering of Massachusetts, and became well known in that part of the country. They are now extinct. The Byfield breed, so popular for many years, originated in the same way. China thus did a good thing for our agriculture fifty years ago and more.

The Wool Interest

SHEEP husbandry in this country has been subject to great vicissitudes. Sheep were imported by the early settlers, by the Virginia colony, as early as 1609, and they increased by 1648 to three thousand. The Dutch West India Company introduced them about the year 1625, but they proved to be too much of a temptation for dogs and wolves, for it is recorded that in 1643 there were but sixteen in that whole colony. They were kept upon the islands in Boston harbor as early as 1633, and two years after there were ninety-two in the vicinity of Portsmouth, New Hampshire. It became the universal practice in the days of homespun for a farmer to keep a number sufficient to cloth his family.

The old "native" sheep was a coarse, long-legged, and unprofitable animal, and there was no improvement made in the breeding till towards the close of the last century, when, in 1793, the first merinos, or fine-woolled sheep, were imported by William Foster of Boston. They were wholly unappreciated, were given to a gentleman to keep, and he, knowing nothing of their value, "simply ate them," and a few years after was buying the same class of sheep at \$1,000 per head. The embargo of 1808 induced many to turn their attention to fine-wool sheep, and soon after very large numbers of merino sheep were imported and distributed throughout the United States, and our modern sheep-husbandry, now grown up to its proportional importance, may be said to date from these importations.

American Horses

WHETHER the horse in general has actually undergone any improvement or not may admit of some question, but it is certain that the horses of this country have been greatly improved within the present century. The chief means of carrying on our early inland commerce, including a large amount of heavy teaming and transportation, was the horse. The public roads were bad, worse even than they are at the present day, and over these the freight of the country, whatever it was, had to be moved in wagons made to be capable of the hardest usage. The modern light carriage would have been comparatively useless in a new country and over such roads, while a speed now seen every day would have been quite unsafe. The mail contracts, even

over a very large part of the country, when the post system was instituted, were based on a speed below four and five miles per hour. But there were no mails previous to 1790; and in 1791, the first year of the mail service, there were but eighty-nine post-offices in the whole country, and less than two thousand miles of post-roads, and on these nine-tenths of the mail-service was done on horseback, the stage service being very small.

A few stage routes had been established at an early date. The first, and at that time the only, stage wagon in America is said to have left Boston for Portsmouth in 1661. The first line of stages between Boston and New York was started in 1732, a coach leaving each city once a month, and fourteen days being required to complete the journey. A regular stage line between Boston and Gloucester, Mass., was established in 1788, and consisted of one open two-horse wagon running twice a week. Besides this there were only four stages which ran into Boston at that time.

It will thus be seen that the social conditions of the last century were not favorable to the improvement of the horse, certainly not to increase his speed, now considered indispensable. Fast trotting was scarcely known at the time of the old "Justin Morgan," foaled in 1793, nor was speed estimated as of special money-value till the invention of the modern light buggy and the improvement of roads; but this quality has now come to be essential to the comfort and convenience of all classes of people. In this respect there can be no question that a great increase has been attained by careful breeding, especially within the last thirty years, while much greater attention has been paid to style, action, temper, form, constitution and endurance, so that the aggregate money-value of our horses has been enhanced by the higher general average of intrinsic good qualities.

But the draught-horse has not been neglected. The Conestoga, a large and heavy breed of horses, used mostly for the purposes of slow work in the drays of our large towns and cities, is extensively raised in some parts of the Middle States, while the Percheron has more recently been introduced and bred in some parts of the West.

The number of horses in this country, according to the last census, was 8,690,219, of which 7,142,849 were on farms, and the balance found in cities and

large towns. This was a gain of more than a million in ten years, for, in 1860, the total number was reported as 7,434,688, of which 6,249,174 were upon farms. The number on farms in 1850 was 4,336,719, there having been no effort made to ascertain the number not kept on farms.

It will thus be seen that the capital invested in horses constitutes a large item in our national wealth; and to this should be added more than a million of mules and asses, the number returned in the census of 1870 being 1,125,415. The extent of our dependence upon this class of stock was never more completely realized than during the prevalence of the epizootic of last year, when the infinitely varied transactions of the country, social, manufacturing and commercial, were so nearly brought to a stand-still for the want of the services of the horse.

What Science Has Done

THE contributions of science to the progress of practical agriculture are by no means small or unimportant. Agricultural chemistry, itself in a state of transition and rapid growth, was never so helpful or so available to the farmer as at the present day. Though Sir Humphry Davy may be said to have opened the door to progress and improvement in this direction, in the early part of the present century, the accumulation of scientific facts was so slow that it was not till 1840 that Liebig announced propositions that opened a new world of thought and study, and awakened the attention of intelligent farmers to the importance of applying the results

of chemical investigations, and, in some respects, essentially modified the practice of all civilized countries.

Other facts might be mentioned to show what science has done to throw light upon the labors of the farm, and what progress has already been made in studying the composition of soils, of manures, of feeding substances, and of plants, while investigation and experiment are still being pushed with such vigor as to promise far more profitable and tangible results in the future.

To this end the National Government has come to the aid of the States in the establishment of agricultural colleges where special attention may be given to the various sciences which bear directly or indirectly upon practical agriculture. All the States have now accepted the grant made by Congress in July, 1862, and, in more than half of them, such colleges have been established and are actually in operation, in some form or other. They will undoubtedly do a good work for the rising generation; but whatever results may flow from them, they seem to indicate that the present is but the dawn of a new era—an era of improvements of which we cannot yet form an adequate conception. They show that a greater application of mind to the labors of the hand is to distinguish the future over all past generations, for the large numbers of young men who will go forth every year from these institutions, many of them thoroughly instructed in chemistry and kindred sciences, will give us, at least, the conditions for new discoveries which will open the way to higher triumphs, and so lead on to the golden age of American agriculture.

Some Nutritional Problems and Anomalies in India



R. RAJALAKSHMI

IT is well-known that nutritional deficiencies abound in many developing countries, sometimes euphemistically so-called, and India happens to be one of them. The per capita availability of land is less than 0.8 acre (about 0.3 hectare) and yields are low. For instance, cereal yields are only about 300–400 kg. per acre, although the green revolution has altered the picture in some areas. The poor diet is based mostly on cereals, and the per capita daily consumption of milk, meat and eggs is less than 100, 5 and 1 g. respectively. These goods are expensive, but even the consumption of leafy vegetables which are available in plenty is less than 5–10 g. (11).¹

The diet is poor in calories, protein, vitamin A and riboflavin. A deficiency of iodine is prevalent in

the goitre belt and thiamine in the rice-eating areas. Deficiencies of vitamin C, B₁₂ and niacin are also to be expected. Although the diets are apparently adequate in iron, iron deficiency anemia is also widespread.

Calories

UNLIKE other nutrients whose availability to the body can be regulated by intake, absorption, and excretion, the supply of calories has to be regulated primarily by intake and there is no device either for automatically getting rid of excess calories or for conserving the available calories by reduced expenditure beyond certain limits. Consequently a deficit and an excess of calories both pose problems.

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¹ Italic numbers in parentheses refer to Literature Cited, p. 23.

It is known that undernutrition in early life can result in serious growth retardation and perhaps permanent stunting of adult stature. It is also suspected that this may be accompanied by irreversible mental retardation. In adults, undernutrition, is said to lower productivity. Both these suggestions have serious social and economic implications and put the developing nations on the defensive.

At our institution, we had a project on pregnancy and lactation. Besides data on these two aspects, this project yielded babies and we were tempted to use them. We predicted that those in the poor group would become seriously growth-retarded after weaning and might become protein-deficient and perhaps also mentally retarded sometime between 1 and 3 years of age. We arranged to get these babies tested on the Cattell Intelligence Scale every 3 months and watched anxiously for the expected result. First, it was rather annoying that the babies kept on disappointing us by maintaining their I.Q.'s even when their body weights became 60 percent of expected weight. Then the realization suddenly dawned on me that, disappointing as it was for our research project, it was great for these children and the society, country and world in which they lived. (12).

In retrospect, we realized that these children, in spite of gross growth retardation, maintained an adequate protein status as judged by serum protein and albumin levels. Their diets provided 10 percent protein calories and corresponded in protein value to a 6 percent casein diet. We wondered whether the picture would be different when the most limiting nutrient was protein rather than calories. Our suspicion was confirmed by our studies on kwashiorkor children in Kerala (13). Parallel studies on rats also showed that at least in the post-weaning period, protein restriction has effects different from those of calorie undernutrition (13). The above results should not be taken to mean that it is all right to undernourish children as long as their protein status is satisfactory. The chronically hungry child is a frustrated crybaby, and we do not know how this would affect his motivation and general outlook in later life. In this connection, animals undernourished in early life are found to show behavioral changes such as hoarding, increased emotionality, decreased exploration, etc. although their performance on complex learning tasks is not affected (14).

Overnutrition in early life also seems to bring its own problems. Individuals who are overweight as children tend to be obese as adults. Further, they exhibit a certain amount of lethargy and slowness. Studies carried out by Frankova (3) show some retardation of neuromotor development in over-nourished animals.

In adults, chronic undernutrition is said to be associated with decreased productivity. But while adequate nutrition may be a necessary condition for high productivity, it does not seem to be a sufficient condition because almost all the material goods in India including our silks and cottons, carpets and rugs, jewelry and ornamental ware, our temples and palaces, hospitals and homes, not to mention our nutrition laboratories, are produced—not by the well-nourished sections of the population—but by undernourished individuals.

It is said that the productivity of the average Indian is only about one-fourth or less of the productivity of workers elsewhere. Be that as it may, the land required by an Indian for the food he consumes at present is far less than that required by his western counterpart, assuming comparable yields. The difference would be still greater in the case of other goods such as water, dwelling area, fuel or power, and consumer goods so that he is also using up the earth's resources at a much slower rate—a significant fact in the light of our present concern about the ecological perils faced by mankind.

A small body size may not always be a disadvantage as people trying to get into smaller cars can vouchsafe. For one thing, basal metabolic rate (BMR) calories are reduced. Further, in the case of most activities, the energy increment required is related to body weight and BMR. In activities for which a greater body weight does not confer an advantage, the smaller individual can perform at less energy cost than larger individuals, as studies carried out by Guharay (4) on Indian and Polish miners show. In other words, a small individual has the advantage of a small car. The apathy and inertia of the undernourished individual is often referred to, but apparently undernourished individuals like Gandhiji in the past and Acharya Vinoba Bhave do not present this syndrome.

The most baffling problems we face in energy metabolism are, however, that (a) children con-

tinue to grow, albeit at a slower rate, despite calorie intakes being apparently less than requirements even for the actual body size, and (b) poorly nourished mothers manage to bring forth fairly healthy babies and nurse them successfully for at least 4 to 6 months (a feat not achieved by the well-nourished upper class) without apparent loss of body weight. These women, maintaining as they do an almost constant body weight of about 40 to 45 kg, do not have to bother about the weight-watchers' club. More intensive studies on the mechanisms by which these adaptations are achieved should be most worthwhile (12).

Notwithstanding anything I have said, I don't like to see hungry faces, and I hope that we shall eliminate hunger, except before mealtime, from the face of the earth.

Protein

IN spite of all that is said about the protein gap in India, common diets contain 8 to 10 percent protein calories, and the main problem seems to be achieving a better protein quality by a judicious combination of cereals, legumes and greens. This can be done if the calorie gap, which is of the order of 300 to 400 calories for most age groups among the poor, is bridged by increasing the intakes of legumes, milk, and greens by 25 to 50, 50 to 100 and 50 g., respectively. About one-fourth to one-third of the individuals have slightly deficient serum protein and albumin levels and they respond to a better diet based on plant foods. In some regions such as Kerala, children in the post-weaning period, however, suffer from serious protein deficiency because foods consumed by the family such as fish, meat, eggs and legumes are denied to them. Often, the onset of diarrhea results in the substitution of tapioca for rice. Protein deficiency in young children remains a serious problem in such regions. Although the percentage of affected children may be small, in absolute terms they run into millions. It is particularly tragic as a deficiency of protein is associated with that of many other nutrients and with mental retardation.

Animal studies have shown turnover rates of protein to be influenced by dietary intake. This might be the case in man on the basis of the low rates of creatinine excretion in Indian subjects, the same being only about 400 mg. in poor women, for instance. A relation between creatinine excretion

and BMR has been suggested and this relation, if applied to our subjects, would give such low BMR's that all the problems faced by us with regard to energy metabolism would be automatically solved! Unfortunately, the few studies made on BMR do not encourage us to take this approach. Certainly, more studies would appear to be needed on this aspect.

Oomen (8) has added a new dimension to this problem by reporting the presence of nitrogen-fixing bacteria in the human intestine under conditions of marginal protein supplies and their disappearance with a better protein status. In studies on school children, we found a negative nitrogen balance at the beginning and end of a 6-month period but they showed some weight gain (0.5 kg) in between. Fecal N in this study was more than 30 percent of dietary N in some cases. We dismissed the data as meaningless. However, Bacon Chow appears to have obtained similar data on control children in a project sponsored by the U.S. Department of Agriculture. In the light of Oomen's findings on New Guinea subjects, the question arises as to whether the picture in these studies has been distorted because of the nondietary origin of part of the fecal nitrogen or whether it is a plain case of indigestion.

Calcium

ORDINARY diets contain no more than 300 to 500 mg calcium. While retarded skeletal development in children is fairly common, rickets and osteomalacia are not as common as might be expected. In the State hospital in Baroda, the number of inpatients admitted annually for these conditions as well as osteomalacia is only about 40 as against a total of about 30,000.

Many of the cases of rickets found in clinical practice seem to be due to renal or renal-tubular disease and are sometimes associated with low levels of phosphorus.

The maternal diet during pregnancy and lactation contains about 400 to 500 mg calcium; but, although the poor women have thinner bones than upper-class women on the basis of cortical thickness of the second metacarpal and the femur, they get no worse with lactation.

A survey of more than 60 middle-aged men and women in a village showed no incidence of either osteoporosis or osteomalacia, but coarse trabeculae

were seen in some cases. Walker in South Africa has found the incidence of osteoporosis to be greater in elderly European women with high calcium intake (800 mg) than in Bantu women of the same age with lower intakes (300 to 500 mg). In this connection, in a study by Henry and Kon (5), animals given low calcium diets in early life were less prone to osteoporosis in senescence than those given a high calcium diet.

In our studies dietary calcium supplementation was found not only to promote bone calcification, but also to increase food intake and weight gain in both animals and children—suggesting that a homeostatic mechanism operates to restrict food intake when the supply of calcium in the diet is deficient. Incidentally, healing from bone injury is found to be quite efficient in Indians and to be unaffected by warm environmental temperatures.

It is often supposed that phytate present in plant foods interferes with the absorption of calcium, but neither animal experiments carried out by us nor human experiments carried out by Walker et al. (16) in South Africa support this view. The very fact that when Indians die they have respectable bones to be preferably cast into the Ganges suggests that their calcium status is not all that bad.

The ineffectiveness of phytate raises the question whether the enzyme phytase is present in the human intestine especially when the diets are rich in phytate. Incidentally, vitamin D is believed to facilitate the activity of phytase.

In our child-feeding experiments, calcium added to a diet based on cereals and pulses is quite effective in promoting bone mineralization. In other studies, vitamin D supplementation was found to be effective. The question whether or not young children in the tropics need dietary vitamin D remains to be answered by more systematic investigation. Although calcium does not seem to pose a serious problem in adults including adult women, it does seem to pose a problem among children throughout the period of growth.

Iron

COMMON diets in this country contain apparently adequate amounts of iron in spite of which iron deficiency anemia responding to iron supplementation is widely prevalent. Factors implicated are intakes below average in many cases, presence

of phytate in the diet, and hookworm and other parasitical infestations.

Animals fed refined flour with salt and vitamin mixtures, however, retain no more iron than those fed whole-wheat flour or the same with added bran. Anemia is common, although not to the same extent, even in urban areas with less incidence of intestinal parasites. Vitamin C intakes are of the order of 10 to 15 mg, and this seems sufficient to maintain blood levels and prevent scurvy. However, low intakes of vitamin C may be a crucial factor in iron nutrition as supplementation of iron with the same results in greater increases of blood hemoglobin (1).

Vitamin A

INDIA has a high incidence of blindness, most of which is believed to be due to vitamin A deficiency. This is easily preventable because many vegetables, fruits, and greens are rich in carotene. Both on the basis of animal and human studies, the utilization of carotene seems to be at least one-half—one-third as against one-sixth assumed by the FAO committee.

Thiamine and Riboflavin

THIAMINE deficiency is prevalent in some areas, but the substitution of undermilled or par-boiled rice and the greater consumption of other grains and legumes can help remove this.

Symptoms of riboflavin deficiency are widely prevalent and seem to be partly due to intestinal parasites. The symptoms appear to increase in winter. According to Mitchell (7), riboflavin requirements increase with cold exposure.

Vitamin C

ACCORDING to Jelliffe (6) infantile scurvy, a dreaded disease in the West till recently, is practically unknown in the tropics and subtropics. This is not surprising as most infants are breast fed till 1 to 2 years and breast milk contains about 3 mg of vitamin C. The surprise is that mothers who are losing about 20 mg in milk and 5 mg in urine do not show scorbutic symptoms on intakes of 15 to 20 mg with the progress of lactation. Nor can this be accounted for depletion during lactation and repletion during the inter-pregnancy levels, as very often a child is nursed till the onset of the next pregnancy. Most Indian authorities are agreed that (a) output of milk is of the order of 700 ml (b) that the same

contains 3 mg percent ascorbic acid (c) that dietary intakes are 10 to 15 mg and (d) that nursing mothers don't have scurvy. Yet the question mark raised by these observations which don't add up right seems to have been missed. The fact of a negative balance during lactation has been confirmed by longitudinal studies involving analyses of milk, diet, urine, and blood (12). Preliminary investigations suggest the possibility of placental synthesis of ascorbic acid, but this needs confirmation by isotope studies. We have heard via the grapevine that Walker in South Africa has also made similar observations.

Vitamin B₁₂ and Folic Acid

THE diets providing as they do less than 5 to 10 g of animal food and 50 to 100 g of milk are also apparently lacking in vitamin B₁₂. But megaloblastic anemia is seldom found in India, which suggests that absorption is efficient. Pernicious anemia is unknown and similar observations have been made in South Africa. On the other hand, while milk levels of vitamins in nursing mothers increased rapidly in response to oral supplementation in the case of other vitamins, the response to vitamin B₁₂ supplementation was poor (2). In several studies, supplementation of either B₁₂ or folic acid or both along with iron did not improve response of blood hemoglobin levels over that with only iron. In this connection, by and large, vegans in Britain who avoid all foods of animal origin including milk have not shown deficiency symptoms. The absence of B₁₂ deficiency has also been attributed to its presence in drinking water possibly because of contamination with sewage.

Serum levels of folic acid are sometimes low in pregnancy, but this may be merely a physiological phenomenon because milk levels of folic acid compare with values reported in the West and serum values also seem to be normal in lactating women. A similar opinion has been expressed by Thomson (15). To add to the confusion, folate supplementation in pregnancy has been reported to increase birth weights even when the hematological picture is normal (*Thomson, personal communication*).

Pellagra

A few cases of pellagra in Hyderabad have been found to be associated with the consumption of

maize or jowar. However, the protein status of people consuming either grain (the whole grain is consumed) is not found to differ from that of others consuming wheat (10). The excretion of N'MN is also in the normal range. Nor is there any noteworthy incidence of pellagra. Animal experiments suggest no difference in nutritional status of rats fed either maize or jowar. They also suggest that in either case the basic deficiency is one of lysine and isoleucine rather than tryptophan or nicotinic acid. It is possible that the consumption of maize grits instead of whole maize as well as the consumption of alcohol have contributed to the etiology of pellagra found early in this country.

Iodine

ABOUT 10 percent of the population live in goitre areas, but only about 25 percent of them are covered by iodized salt.

Other problems such as osteofluorosis and kidney stones are present and a number of dietary nutritional factors have been implicated (9).

On the basis of intakes, we expect to find deficiencies of calorie, protein, calcium and vitamin A, and we do find them. We do not expect a deficiency of iron, but find one. We expect to find deficiencies of vitamin B₁₂ and folic acid, but do not. Even in the case of calories, protein and calcium there seems to be some adaptation to low intakes, but such adaptation presupposes a minimum supply of nutrients and does not imply the suspension of the law of conservation of matter.

Solutions

FORTIFICATION of commonly consumed foods with the critical nutrients has been suggested, but this involves a degree of centralized distribution which would be rather expensive for a poor country like India. We have not been able to achieve even the full scale distribution of iodized salt in goitre areas.

Fortification of commodities like wheat flour requires its refinement for better keeping quality, and this would result in loss of both bulk and nutrients.

Diversification of agricultural production combined with nutrition education, in our opinion, may

be suited better to the genius of the country. The project sponsored by the USDA currently aims to improve child nutrition by using locally available

resources. This approach emphasized by us strongly since 1964 has now become a widely accepted one in India.

LITERATURE CITED

- (1) BAGCHI, K., AND CHOWDHURY, S.
1955. ROLE OF ASCORBIC ACID IN THE ABSORPTION AND UTILIZATION OF IRON. *Indian Jour. of Medical Research*, 8: 856.
- (2) DEODHAR, A. D., RAJALAKSHMI, R., AND RAMAKRISHNAN, C. V.
1964. STUDIES ON HUMAN LACTATION—PART III. EFFECT OF DIETARY VITAMIN SUPPLEMENTATION ON VITAMIN CONTENTS OF BREAST MILK. *Acta Paediat.* (Stockh), 53, 42.
- (3) FRANKOVA, S.
1968. NUTRITIONAL AND PSYCHOLOGICAL FACTORS IN THE DEVELOPMENT OF SPONTANEOUS BEHAVIOR IN THE RAT. In: *Malnutrition, Learning and Behavior*, Eds. N. S. Scrimshaw and J. E. Gordon, p. 312. M.I.T. Press, Cambridge.
- (4) GUHARAY, S. R.
1972. COMPARATIVE STUDIES ON ENERGY METABOLISM AND PHYSIOLOGICAL WORKING CAPACITY IN INDIAN AND EUROPEAN COAL MINERS. In: *Perspectives in Nutrition*. Ed. R. Rajalakshmi, University Press, Baroda, India.
- (5) HENRY, K. M., AND KON, S. K.
1953. THE RELATIONSHIP BETWEEN CALCIUM RETENTION AND BODY STORES OF CALCIUM IN THE RAT. EFFECT OF AGE AND VITAMIN D. *British Jour. Nutr.* 7, 147.
- (6) JELLIFFE, D. B.
1955. INFANT NUTRITION IN SUBTROPICS AND TROPICS. WHO Monogram series No. 29.
- (7) MITCHELL, H. H.
1964. COMPARATIVE NUTRITION OF MAN AND DOMESTIC ANIMALS. Academic Press, New York.
- (8) OOMEN, H. A. P. C.
1972. POSSIBLE SIGNIFICANCE OF THE HUMAN INTESTINAL FLORA IN PROTEIN NUTRITION. In: *Perspectives in Nutrition*. Ed. R. Rajalakshmi, University Press, Baroda, India.
- (9) PATWARDHAN, V. N.
1961. NUTRITION IN INDIA. *Indian Jour. Medical Sciences*, Bombay 4.
- (10) RAJALAKSHMI, R.
1969. APPLIED NUTRITION. Biochemistry Dept., Baroda University, India.
- (11) RAJALAKSHMI, R., AND RAMAKRISHNAN, C. V.
1969. DIETARY AND NUTRIENT ALLOWANCES FOR INDIANS. *Pl. Fds. Hum. Nutr.* I, 163.
- (12) RAJALAKSHMI, R., AND RAMAKRISHNAN, C. V.
1969b. GESTATION AND LACTATION PERFORMANCE IN RELATION TO NUTRITIONAL STATUS. Terminal report PL 480 project FG-In-224. Biochemistry Dept., Baroda University, India.
- (13) RAJALAKSHMI, R., AND RAMAKRISHNAN, C. V.
1969c. NUTRITION, LEARNING PERFORMANCE AND BRAIN BIOCHEMISTRY. Terminal report PL 480 project FG-In-176. Biochemistry Dept., Baroda University, Baroda, India.
- (14) RAJALAKSHMI, R., AND RAMAKRISHNAN, C. V.
1972. NUTRITION AND BRAIN FUNCTION. *Wld. Rev. Nutr. Diet* 15, 1.
- (15) THOMSON, A. M.
1971. NUTRITION IN PREGNANCY. *Brit. Jour. Hospital Med.* 197, p. 600
- (16) WALKER, A. R. P., FOX, F. W., AND IRVING, J. T.
1948. STUDIES IN HUMAN MINERAL METABOLISM. I. THE EFFECT OF BREAD RICH IN PHYTATE PHOSPHORUS ON THE METABOLISM OF CERTAIN MINERAL SALTS WITH SPECIAL REFERENCE TO CALCIUM. *Biochem. J.* 42, 452.

FOREST PEST MANAGEMENT

A Research Challenge

W. E. WATERS



MANY of us in forestry are deeply concerned about the dilemma we often face when trying to decide whether or not to take action against a destructive insect or disease. Even when we are given a go-ahead to begin a treatment, we wonder whether the one we select will really do the job, whether it will pay off in values gained, or whether it will set off a chain of adverse environmental side effects. Once the treatment is decided upon, however, we stoutly affirm that the action is necessary because of the seriousness of the situation and that it is the best we can do with available technology and resources. But we have not been fully aware of how short we are in knowledge and technology, funds, and manpower to make sound, defensible decisions.

The hard fact is that in spite of significant advances in pest control technology we have not really resolved a single major forest insect or disease problem in the United States. Moreover, in the light of recent constraints on pest control practices, especially those imposed on pesticide use, we have fewer weapons in our arsenal of defense against some pests than we had a decade ago. And in the case of some important tree species and related resource values, we have some doubts as to whether we have even put our fingers on the most critical insects and diseases.

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At present, a number of major pests are present in outbreak numbers. These include the Douglas-fir tussock moth, the western and eastern spruce budworms, and the southern pine beetle. Many other insects and diseases are destroying untold amounts of timber and seriously affecting other forest-related resources. Among these destroyers are the mountain pine beetle, western pine beetle, Douglas-fir beetle, fir engraver, *Ips* beetles, balsam woolly aphid, dwarf mistletoes, *Poria weirii*, blister rust, fusiform rust, and annosus root rot. A number of introduced insects are spreading into new areas and creating new problems in the process. Such pests are the larch casebearer, gypsy moth, red-pine scale, and Sclerodermis canker. Individually and collectively, these are the real-life problems to be solved.

Fundamental Voids

WHERE do we stand in the face of such problems?

We do not have an adequate system for measuring, evaluating, and predicting insect- and disease-caused impacts. We observe and record—in diverse ways—defoliation, growth loss, mortality, and other direct effects of insect and disease activity. But we do not have consistent, agreed-upon criteria and baselines for judging what these mean in ecological or in socioeconomic terms. Very simply, we do not have wholly defensible bases for deciding if, when, and where to initiate control actions.

With only a few exceptions, we do not have biologically meaningful and statistically sound methods of sampling pest populations. We do have satisfactory means of estimating the numbers and volumes of trees affected and the acreages involved. But we need to have reasonably accurate estimates of insect population densities and disease incidence in order to (a) analyze their fluctuations over time and among places, (b) evaluate experimental control treatments, and (c) provide a quantitative basis for other vital research purposes. Furthermore, we need reliable estimates to assess current population levels and determine trends for surveys and control decisions. If we do not have good basic data on pest numbers, we cannot expect to have valid mathematical models. Yet we look to these models to give us insight into the factors or processes that make pests act as they do and from which we make

predictions of future numbers and damaging effects. Without sound sampling procedures, we are on shaky ground in all aspects of our research and action programs.

How much do we really know of the population dynamics and epidemiology of even our most destructive insects and diseases? It is true that detailed studies, including the gathering of quantitative data, have been made of a number of primary forest insects and diseases. However, these studies generally have been limited as to number of locations and timespan. For example, little if any data have been taken when and where pest populations are low. As yet, we do not have for any major pest the key to the factors or processes that determine its variation in abundance among places and its changes in numbers or rate of infestation over time for the full range of conditions under which it occurs. Pieces of the puzzle, yes—the whole picture, no.

How, then, can we decide rationally where to put our research emphasis? What control technique or strategy should we give highest priority? How, in fact, do we really evaluate the effectiveness of even a single treatment? Put another way, how can we specify in advance what is the level of satisfactory performance for that treatment? In the longer view, how can we realistically hope to put together optimal control strategies against our major pests without a fundamental quantitative base of knowledge of their population dynamics?

Shotgun Approach

OUR approach to the field testing of new control techniques is painfully inadequate. This is particularly true of recent efforts with candidate insecticidal chemicals, but it applies as well to field experiments with microbial agents, behavioral chemicals, parasites and predators, and other materials and methods.

If we look squarely at the record of the past 10 years, we see a wide scattering of field trials against a variety of pests and a continuing series of shotgun blasts against certain major pests. As a consequence, we now have an impressive list of materials and techniques that show great promise but are not quite ready for operational use. Seemingly, we have become resigned to the futility of trying to design and

conduct a really adequate field experiment that will provide definitive answers. There have been some outstanding exceptions, of course, where imagination, initiative, and adequate funds have produced an effective project. But these are rare.

Time is a critical factor now—and it always has been—in the field of forest pest control. The shotgun approach to field experimentation produces uncertainty and controversy, and it is wasteful of time and money in the long run. The problem is even more critical with some of the new materials (such as the insect viruses and behavioral chemicals) and new methods (genetic controls, for example), where more variables are involved and the ecological interactions are more complex. If we are to advance in our technology of pest control and improve our arsenal, we will have to do a much bigger and better job of field experimentation than heretofore.

Further Complications

COMPLICATIONS and constraints also arise from recent legislation and social pressures. Pesticides, of course, are the focal point of much public debate and political interest. But all pest control practices are subject to scrutiny, and this puts new demands on the entire research and development process. The Federal Environmental Pesticide Control Act of 1972 (Public Law 92-516) contains provisions that call for more emphasis on safety to nontarget organisms and to humans involved in the production or manufacture of pesticidal materials, for temporary permits for experimental uses, and for more intensive monitoring of pesticide effects in treated environments. More data—and different kinds—will be needed to meet these and other requirements of the law.

The requirements for thorough evaluation of potential environmental impacts of pest control activities—through environmental impact statements as required by the National Environmental Policy Act of 1969—are becoming more stringent as a result of new guidelines by Federal agencies, judicial decisions, and other pressures. State legislatures and regulatory agencies have been just as active as their Federal counterparts. All of this adds up to increased responsibility in the development of acceptable decision criteria, as well as improved techniques, for managing destructive pests.

The Brighter Side

FOREST pest management may seem to be an impossible task, but I am confident that we can achieve the goal of sound operational systems for effectively managing the critical insects and diseases that threaten our forest-related resources. Although there are fundamental voids to be filled, advances in technology and greatly increased political interest together give us more tools to work with and improve our chances of gaining needed support. We have a better understanding now of what insect- and disease-caused impact really means. We know that it has ecological and socioeconomic components and that these must be fully identified, quantified, and evaluated in order to reach any conclusions or make a decision in each case. Some mathematical procedures for this have already been developed.

The concept and definition of impact and its components, and the interrelations of protection with other aspects of resource planning and management decisions, were spelled out at a special work conference at Marana, Ariz., in February 1972. Forest Service people joined with key individuals from State and private organizations in making recommendations for an action plan to develop a national data base and information system in this problem area.¹ In the meantime, specific impact data inputs are being gathered and analyzed on the mountain pine beetle, larch casebearer, tussock moth, gypsy moth, southern pine beetle, the slash pine seed complex, and some other major insect pests. The same is being done on diseases such as dwarf mistletoes, annosus root rot, fusiform rust, and oak wilt.

New Techniques and Materials

SAMPLING techniques and procedures have been developed for particular stages of some major insects. Some of these procedures have not been tested or applied in a practical way, but a good start has been made. A considerable amount of information on different kinds and sizes of host tree units has been gathered on most major insects. This information, properly analyzed and supplemented by analyses of data from well-designed sampling studies, could provide the kind of sampling schemes

¹ Impacts of insects and diseases on uses, values, and productivity of forest resources. Unpublished report., U.S. Department of Agriculture, Forest Service, 64 pp.

we need. Sampling procedures have been devised for certain canker-forming diseases and dwarf mistletoes. These, too, could be further developed for more precise estimation of disease incidence and prediction of spread.

Over the years, intensive observations have been made of the life history, behavior, and population ecology of many insects that cause damage to forest trees. In recent years, detailed life table studies have provided more insight into the population dynamics of some primary pests such as the mountain pine beetle, eastern spruce budworm, gypsy moth, and European pine shoot moth. Partial life tables have been made of the western pine beetle, jack pine budworm, forest tent caterpillar, dwarf mistletoes, and some others. Such studies have provided clues to the factors determining the abundance of these pests.

Conceptual and empirical mathematical models have been developed to describe, analyze, and predict changes in population numbers of certain insects. Other models have been devised for individual relationships and processes, such as predation, that affect survivorship and population characteristics. Although these models have not been fully validated, they provide a somewhat advanced base of knowledge and some grasp of the mathematical intricacies and biological subtleties of modeling such phenomena.

Less work has been done on the epidemiology of forest tree diseases, and few mathematical models have been developed to depict disease characteristics. But the recent application of mathematical analyses to certain dwarf mistletoe and annosus root rot characteristics show promise.

Recent research has provided leads to a number of new approaches to forest insect and disease control. Significant findings have been made with safer and more selective toxicants, potent behavioral chemicals, microbial agents (primarily viruses and bacterial insecticides), more efficient parasites and predators, genetic controls, host resistance, and manipulation of the physical environment of forest stands. Suffice it to say, we have a larger array of potentially useful control techniques to direct against target insects and diseases than even before.

The Legal Side

IN the area of legal constraints, the U.S. Department of Agriculture has been working closely with

the Environmental Protection Agency to develop guidelines for safety evaluation of the polyhedrosis viruses and behavioral chemicals for registration as pesticides. The virus guidelines are essentially completed and will be formalized soon. Guidelines on the behavioral chemicals should follow shortly. Through the Federal Working Group on Pest Management—a working arm of the Council on Environmental Quality which handles matters of both policy and implementation on pest management programs in the Federal Government—the needs of forest insect and disease research and action programs will be kept visible and viable.

Putting It All Together—Total Pest Management

TO achieve the goals of effective forest pest management, it is clear that we have to raise our sights. The stakes are increasing and we cannot hope to really surmount pest problems at our present pace and with present resources. The task is larger and more complex than we have ever envisioned.

First, we must have a greater capability to respond to emergency needs, such as the current tussock moth situation in the Northwest. We must have the resources to take on the job of finding short-term solutions at a level of effort that will provide definitive answers in the timespan required. Improved and more intensive pest survey systems will reduce the frequency of emergencies, but some pest problems arise in a way that will never permit extensive, long-term studies to provide answers.

Second, in the longer view, we must recognize that the unilateral approach to forest insect and disease control—continued application of chemical, biological, or cultural methods on a whatever-seems-best-at-the-moment basis—provides no real solutions. We need to establish the concept and objective of total forest pest management. And we need to move vigorously toward this objective by planning, organizing, and carrying out the research and development programs required to achieve operational systems for managing the major pests at least.

What would such research and development programs entail? What are the probable costs and time frames?

Right off, we can say that the makeup, costs, and time schedule of any such program will depend on the pest involved, how much we know about it and

its impacts on resource values, and the state of technology on control techniques and strategies that might be directed against it. However, we already have some experience in structuring this kind of program.

Hard Decisions

THE total pest management approach requires a concentration of effort on a limited number of major pests. This calls for some hard decisions. The Forest Service can and should take the lead in this. But here, too, strong cooperation is needed. Other Federal agencies and all State and private organizations concerned with forest pest problems should participate in the selection of the target pests and in the general planning of the programs. As each program is generated, all individuals and organizations involved should commit themselves to carrying out their part as planned and scheduled. Plans are now being developed for coordinated pest management research and development programs on the western spruce budworm, larch casebearer, and dwarf mistletoes. Plans for westwide coordination of effort

on the western pine beetle and mountain pine beetle are next in line.

In this regard, the pine bark beetle subprogram of the IBP-NSF² project on principles, strategies, and tactics of pest population regulation and control in major crop ecosystems has served as a great catalyst to research by the Forest Service and other organizations on the western pine beetle, mountain pine beetle, and southern pine beetle. Present and expanded efforts by the Forest Service and other cooperators can be merged directly with the IBP-NSF project to mutual advantage.

In summary, we are far in arrears in the knowledge and technology needed to get on top of even our most critical insect and disease problems. The total job of forest pest management is becoming more complex and demanding. The challenge is clear. We must greatly strengthen our efforts or we will remain where we are today—uncertain and unprepared.

² International Biological Program, funded through the National Science Foundation, directed by Carl B. Huffaker, University of California, Berkeley.

BEHAVIORAL CONTROL OF OBESITY

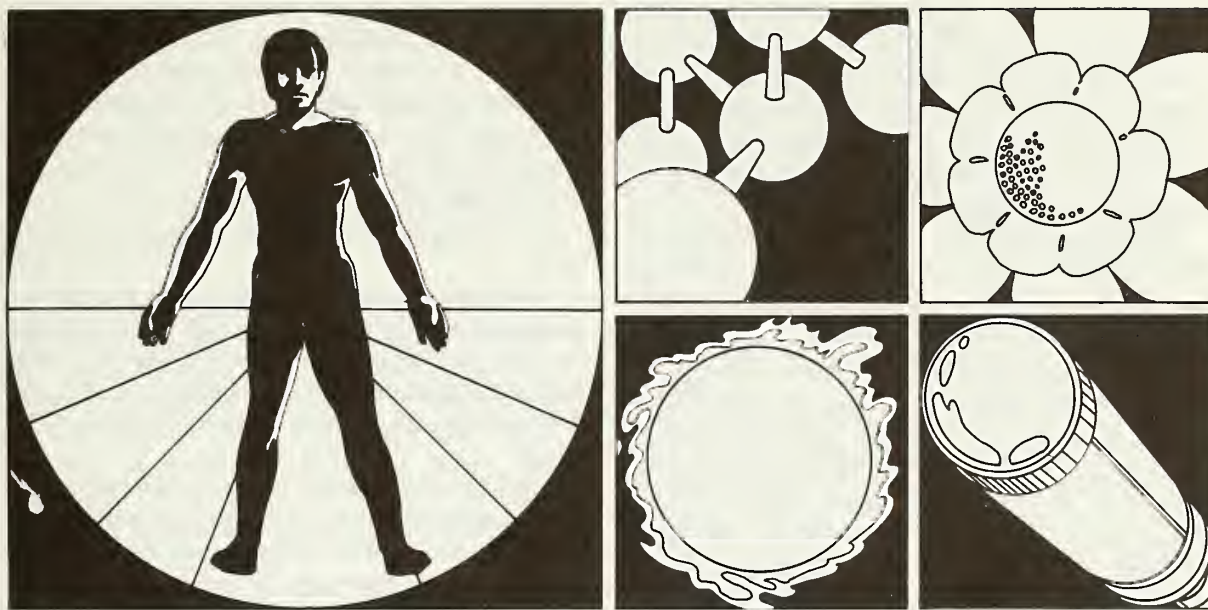
FOOD nutritionists at Lincoln University, Missouri, are studying the nutritional and psychological approaches to behavioral control of overeating—and the obesity that often follows.

Barbara Paulsen, coordinator of the project, says that simple reduction of calorie intake has helped from 15 to 25 percent of the obese population to lose weight, at least temporarily. More people could lose weight, however, by using techniques from behavioral psychology. The trouble is, according to Professor Paulsen, not enough nutritionists are trained to adequately apply these principles. And

since increased mortality and morbidity are reported to be associated with obesity, controlling weight is highly important.

As a part of the research study, 60 female subjects, of whom 15 to 60 percent are overweight, will participate in a 15-week weight reduction program that stresses both proper nutrition and behavioral techniques.

After the project is finished and data are available, trained nutritionists will train paraprofessionals who in turn will try to reach the underprivileged where the greatest incidence of obesity occurs.



The Best of Agricultural Science Review

WHEN the decision to discontinue *Review* became official, the staff began to reminisce about the highpoints of the magazine's existence. The end of an era. . . . What marks did it leave? The answers were not hard to find.

In each instance, the determining factor was reader response. Oddly, agricultural scientists offer meager feedback to a journal editor. But when a particular article did strike a reader as being useful, inspiring, or stimulating, the *Review* editor was sure to hear about it.

The staff thought it fitting, therefore, to identify those articles which deservedly can be called "the best of *Agricultural Science Review*," and to share with our present readers selected quotes and excerpts from this group. These are cited chronologically, beginning with the early issues.

For those who have a sense of history in their souls, it seems appropriate to mention that while the editorial of the very first issue—"The Language of Science"—was being written, the shattering news of President Kennedy's assassination reached our

ears. We had just written the words, "Ignorance of science is detrimental both to the public welfare and to the scientific community itself."

And in the awful, quiet moments that followed, we could not help thinking of the many times the President himself had signaled a yearning to know more of the mysteries of science. "Tell me *why* radio waves act the way they do," he had asked his science adviser only months before. Not *how* radio waves act, for he already knew that, but *why*.

This yearning for new knowledge about science, we felt, surely must be a sign of the era. . . . and thus was molded the philosophy of the new journal which we were launching. It was reflected in a different form on page 1 of Volume 1, Number 1, under the byline of the founder of *Review*, T. C. Byerly, as he wrote: "Man can never disassociate the fruits of the soil from his own welfare, nor from his pursuit of knowledge in other areas."

IN Volume 2, Number 3, appeared the first of a series of significant articles by Nobel laureates—

this one by George W. Beadle, titled "The New Biology and the Nature of Man." Its informality is due partly to the fact that the text was transcribed from a lecture which he had delivered solely from notes. We suspect, however, that the author's lucid style also denotes a rare skill to communicate science information in understandable fashion:

"In one sense I might say I begin this talk with the humanities, for I start with the consideration of the oldest living language. It is at least 3 billion years old, and a remarkable language it is. It exists only in written form, that is, 'written' in submicroscopic molecular code. It is remarkably simple, for it has only four letters. Each of these is one two-hundred-millionth of an inch across. Each is made of but five kinds of atoms—carbon, hydrogen, oxygen, nitrogen, and phosphorus—and there are only about 32 atoms in each letter. All the words in this language appear to be 3-letter words, and there are only 64 of them possible. This beats Basic English by a very wide margin. Most remarkable of all, this language is the only language known to have a built-in capacity for copying itself. There is no need for secretaries, typewriters, or printing presses.

"It is a language in which the specifications for all living organisms, from viruses to man, that have ever existed on earth are written.

"The number of letters in the specifications for these organisms varies from 5,000 letters for the specifications of the simplest known virus to 5 billion for the specifications of man. That's over a million-fold difference. What is the name of this language? I call it DNAese, because it is contained in deoxyribose nucleic acid molecules, which we call DNA."

ONE October morning in 1964, CSRS Administrator T. C. Byerly called the *Review* editor into his office and handed him a copy of a paper that some newspaper reporter had delivered at a science seminar. "I think we ought to consider reprinting this in our journal," he said. "Look it over and let me know."

The title of the paper was "Do They Dig You Daddio or Are You Way Out?" The author was Russell G. Lynch, award-winning science reporter for the *Milwaukee Journal*. Eventually, Lynch's adapted article appeared in *Review* as "Linguistic Barriers in Science Writing" and became the most

widely read piece we ever published. USDA's Director of Science and Education, Dr. Nyle C. Brady, asked that a reprint copy of the article be placed in the hands of every scientist in the Department. It also caught the eye of a discerning Congressman and appeared, with appropriate comment, in the *Congressional Record*.

Here are a few selected gems from Russ Lynch's piece:

"Beatniks use a peculiar lingo which is meant to exclude others from their private little world. Some scientists and technologists are guilty of the same kind of snobbishness when they use jargon. The cost is a breakdown in communication which they can ill afford.

"Lack of communication is particularly serious in natural resource fields, where research and studies must solve problems or develop approaches to them. Men assigned to these tasks are too inclined to confine their discussions to the knowing circle. After they reach decisions or prepare plans, they spring their proposals on the public and expect them to be received gratefully and implemented. This seems to me a major reason why progress has been so slow toward wise management of resources.

"It is important that the public be taken along on the whole trip. Usually some changes are required, support must be generated, money must be provided. People just do not accept changes unless they are convinced by good reasons. They or their representatives will not dig up money for things not understood. Except when they are frightened, I should say, and that provides a valid excuse for such a vulnerable document as *Silent Spring*.

"People are not compelled to listen to you or read your papers. You are in a buyer's market, competing with murder, rape, politics, lukewarm war, aerospace travel and comics in the newspapers; entertainment on television; and sex, whodunits and westerns on drugstore book counters.

"At the very least, you must make what you say understandable, and if you have the talent you had better make it interesting, too.

"Regard it as a challenge, for that it surely is!"

ONCE in a while an editorial in *Review* seemed to catch the fancy of readers and set off streams of letters to the editor. One of these was written by famed chemist, Joel H. Hildebrand, of the Univer-

sity of California. He titled his editorial, "Some Observations by a Practical Gerontologist." It is reprinted here in full.

"My springboard for this "guest editorial" is "Research on Gerontology" by Dorothy Dickins, which appeared in the 1964 fall number of this journal. Its content may be paraphrased as: Some persons are born old; some achieve old age; some have it thrust upon them.

"James Whitcomb Riley's "Grandfather Squeers" had some of the concomitants of age thrust upon him. "So remarkably deaf was my Grandfather Squeers that he had to wear lightning rods over his ears to even hear thunder, and oftentimes then, he was forced to request it to thunder again". But he was not old in spirit. "He said, when he'd rounded his three score and ten, 'I've the hang of it now, and can do it again'".

"The significant distinction between the young and the old is situated not in their bodies but in their minds. The young are alert to ideas; the old are indifferent or mistrustful. But there is impressive evidence that the pleasures of using the mind can continue far beyond any arbitrary age deadline.

"Galileo completed his greatest work, "The Two New Sciences," at 72, when old in body and a house prisoner of the Vatican; Nobel Laureates Debye and Giauque, 81 and 70 respectively, are today publishing important research papers; Goethe completed "Faust" at 80; Verdi was 80 when he composed "Falstaff"; Voltaire was 65 when he finished "Candide," his most famous work; Michelangelo was busily occupied as both a sculptor and an architect till his death just short of 90; Bach composed the superb "Musical Offering" at 62.

"It is true, as has been asserted, that few scientists do any really creative work after the age of 35. However, only a few do so before the age of 35.

"A grandson of mine, about 8 years old, was pouring forth a veritable stream of thoughts and questions. I asked him, "Chris, where do you get all these ideas?" He replied, "When I go to bed I think and I think, and next morning the thinking turns into ideas." Happy indeed is the person who can think and think, and get ideas. I know of no better fountain of youth this."

Joel H. Hildebrand
University of California, Berkeley

IF the editorial staff had been asked to name a particular issue of *Review* that excelled all others, the answer would have been Volume 4, No. 2—simply because of the array of famous authors included in the bylines, and, quite understandingly, the wisdom of their utterances.

From Nobel laureate Selman A. Waksman's article, "Microbes and the Survival of Man on Earth":

"Certain questions have been raised earlier as to the justification of spending much effort in developing a field of science that has yielded what was previously considered to be limited practical results. This was pointedly expressed in the late thirties by a member of the U.S. Department of Agriculture, who said, "I know of no field of knowledge that has contributed less, for the efforts spent, to practical developments than has soil microbiology." Only 10 years later, however, another eminent leader in agriculture in this country made the following statement:

"If all the agricultural experiment stations of this country had contributed nothing else of practical importance than streptomycin, all the expenditures involved in all the experiment stations throughout their whole existence would have been fully justified.

"This particular antibiotic—as well as the numerous others that have found important practical applications—is produced by the actinomycetes, a group of soil micro-organisms. These chemical products have revolutionized medical and veterinary practice and have added untold wealth to our economy."

From "Agricultural Research: A Key to Understanding Our Environment," by Daniel G. Aldrich, Jr., Chancellor, University of California at Irvine:

"As recently in our history as the early 1930's, a few scientists who worried about this country's loss of topsoil were simply voices crying in a wilderness of disinterest. Farmers were barely aware of their own problem. If they were, they know little that they could do about it. City people cared less.

"Today, across an increasingly urban country, soil conservation is almost a social movement.

"I am convinced that agricultural research, which has responded successfully through all of its history to the needs of people, must find the means to meet their broader needs today.

"The pressure on land and the total of our na-

tional resources is intense and growing. The agricultural problem-solving philosophy that brought overwhelming abundance is capable of the same success in new directions."

From "The Agrarian Tradition and the New Science," by Don K. Price, Harvard administrator and president-elect of the American Association for the Advancement of Science:

"In the atmosphere of the 1930's it was very easy to feel that American society had fundamentally gotten off the track a century before—that the strength of the great industrial corporations had come to dominate our politics more than it had any right to do. The world of agriculture seemed to still represent the early Jeffersonian dream.

"If I were to try to reconstruct a philosophy of agrarianism for a modern age, I would appeal to Jefferson in action against Jefferson on paper. We ought to be able to rise to the highest level of using the highest type of science available in our society without regard to the institutional dogmas of the late 18th century. In short, if I were forced to profess a specific traditional political philosophy—which would be an uncomfortable position at best—I would be more tempted to start with the agrarian tradition than any other one I could think of. My philosophy has four essentials:

"First, the ability of an administrative system to protect freedom by decentralizing within its own establishment.

"Second, the predominance of the genuinely popular interest in our country against any form of privilege.

"Third, a concern for the quality of our civilization against the accumulation of mere wealth or the enlargement of mere technical power.

"Fourth, a faith that science still has the potentiality for being a force for liberation of the human spirit, rather than for its oppression of mankind."

IN the summer of 1966, three USDA animal scientists proposed writing an article about the importance of ruminant livestock. Quite a natural topic, we thought, for men who had spent many years of productive endeavor performing experiments with farm animals. When the *Review* office received their manuscript about 6 months later, the editor suspected it would be a milestone article when published. It was. Readers were still writing

for reprints 5 years after the issue came off press. Parts of the article were widely quoted in both professional and popular journals. Here, from one of the opening paragraphs, is the premise of "Ruminant Livestock—Their Role in the World Protein Deficit," by L. A. Moore, P. A. Putnam, and N. D. Bayley, from Volume 5, Number 2.

"Although the emphasis on cereal and oilseed proteins has some basis, relegating animal agriculture to a passive contribution to world food deficits indicates a failure to appreciate the full impact of feed inputs into livestock production. We contend that generally accepted concepts regarding the efficiency of livestock production in terms of use of available resources are erroneous. We contend that because livestock use forages and other feeds inedible to humans, the use of limited amounts of cereals as livestock feeds can enhance the efficiency of producing proteins for humans *in terms of total food resource utilization*. Furthermore, there are promising research leads which, if exploited, can markedly increase the efficiency with which animal proteins can be produced. We also contend that considering the world food deficits solely in terms of amounts of protein or calories may result in answers which will make only the less desired diets available to the 'have-nots' and may aggravate the serious sociological problems of the world rather than reduce them."

ONE *Review* article that drew an unusually heavy response from readers actually had very little to do with science. It was Edwin L. Peterson's piece, "Why Don't Students See Orion?" which appeared in Volume 5, Number 4. "Prof" Peterson, who had just retired from the University of Pittsburgh, jotted down a series of "notions" that revealed the essence of what makes a great teacher. Three of those notions deserve to be included in *Review's* "hall of fame."

Notion No. 1

OFTEN I am shocked to realize that many of my students never see the heavens. They live in cities or in heavily populated suburbs, and the street lights blind them to the stars. Mention Orion to most students, and they look at you in bewilderment. They have read about the Great Dipper, some of them, but they have never lain on the top of a hill and

watched the constellation move about the North Star. Strange world that wants to put a man on the moon but that cannot look at the stars!

Notion No. 8

IN my day as a student we “took” teachers, not courses. Today, I think, the student takes courses regardless of the teacher. The student may be right in doing so. Perhaps the content of the course is more important than the teacher’s attitude towards it and towards other things. And yet I wonder. It seems to me that I remember very little information that my courses gave me. Today I should find it difficult to translate a Latin paragraph, a Greek poem or even, I fear, a passage from *Beowulf*. I could not prove a geometrical theorem, nor could I quote accurately the second law of thermo-dynamics. Yet I remember clearly my extra curricular teacher of Greek, the world weariness of my Old English teacher, the geometry teacher who stared out the window one morning and said, “Geometry is so right it’s a little like God,” and the chastening fear that entered my mind when my physics teacher explained the philosophical implications of the second law of thermo-dynamics implications that altered many of my traditional religious concepts. Few teachers would have dared to interpret the fact or theorem as he did, and I am eternally grateful to him for doing so. Most of my courses and their content I have almost forgotten, but the few great personalities I knew as teachers I shall know always. I have a feeling that today students, especially undergraduates, take courses rather than teachers. I hope I am wrong.

Notion No. 9

THE information presented in a course has little value unless it is so taught that it stirs up something in the student himself. “Music,” said Walt Whitman, “is that which arises in me when I am reminded by the instruments.” Great education and great teachers furnish many reminders.

WHEN Ray F. Smith’s article, “Integrated Control of Insects—A Challenge for Scientists,” appeared in Volume 7, Number 1, in 1969, a nationally known science writer picked up one segment of it to illustrate the fact that a “silent spring” really

did happen once in Peru. The resulting wide publicity again helped to bring a *Review* article to the pages of *Congressional Record*. Here is the new famous “Cañete Valley story.”

“A classic example of what can happen when a pest control program ignores ecology and relies on unilateral use of chemical pesticides is that of the Cañete Valley (Peru) story. Here, during the pre-DDT regime, chemical control of pests of ratoon cotton (second and third year cotton) was based mainly on arsenicals and nicotine sulphate. During 1943–48 the average annual yield was about 470 lbs/acre. Because of a heavy *Heliothis* and aphid outbreak in 1949, the average yield dropped to 326 lbs/acre.

“From 1949 to 1956, growers relied heavily on the new exciting organic insecticides such as DDT, BHC, and toxaphene. Some cultural practices were modified to increase yields. New strains of *Tanguis* cotton were introduced and more efficient irrigation was practiced.

“At first these procedures were very successful. Cotton yields nearly doubled. Farmers were enthusiastic and got the idea that the more pesticide they used the better the crop would be. Insecticides were applied like a blanket over the entire valley. Trees were cut down to make it easier for airplanes to treat the fields.

“But then things began to happen. Birds that had nested in the trees disappeared, along with insect predators and parasites. One by one the new chemicals became ineffective as resistance developed. Finally, as insects became rampant in the cotton fields, the 1955–56 season was an economic disaster. In desperation, growers appealed to their local experiment station for help. With the help of the Ministry of Agriculture, a new, integrated control program was set up, and within a season or two the situation vastly improved. Today, cotton yields in the Cañete Valley are the highest in its history, averaging more than 700 lbs/acre.”

NOTHING pleases a scientist more than to be noted and quoted by his or her peers. One *Review* author who was particularly fortunate in this respect was Sarah M. Shoffner, whose article, “Self Concept—Its Role in Breaking the Poverty Cycle,” (Vol. 7, No. 3) has been widely cited by social scientists in other journals. The three paragraphs we

quote here give a hint as to why the article interested so many readers.

"Recent research has given new credence and validation to the old maxim: "To enlarge what a man can do, you must first enlarge what he *thinks* he can do." There is now further reason to believe that in order to upgrade the aspirations and expectations of rural youth—or even adequately measure them—close attention must be given to self-concepts.

"Evidence seems to imply that people important to another person can profoundly influence that person's self-concept. As might be expected, both family status and quality of the environment are significant factors in influencing self-concept. More important, there is a growing body of evidence indicating that significant relationships exist between self-concept and both educational and vocational aspirations.

"Three steps have been suggested in the handling of a student with a negative self-concept: (a) Trying to prevent the concept from becoming established, or—where such a goal seems improbable—establishing an atmosphere of mutual respect to prevent future inhibition of ability, (b) establishing oneself as a significant other person by recognizing and acknowledging something worthwhile in the student, and (c) encouraging exploration in socially acceptable ways."

WHEN *Review's* editorial board member, James G. Horsfall, then Director of the Connecticut Agricultural Experiment Station, was asked in 1970 to speak to the deans of instruction of New England colleges and universities, he chose the topic, "A Farmer Views the Environment." In his opening ad-lib remarks he mentioned that since college days he had always been scared of deans. We suspect, however, that his audience held him somewhat in awe because of his high standing as a scientist and his witty, philosophical manner of expressing his ideas. Here are selected excerpts from the adapted version of Dr. Horsfall's talk that appeared in Volume 8, Number 1.

"Most of the environmental excitement is among city men. It is they who are frightened, because they have suddenly discovered that Nature fights back.

"This quality of Nature is hard for the city man to understand, for he had always thought of Nature

as being soft and kind. He was accustomed to using the term, 'Mother Nature.' He prattled about the mystical balance of nature. He always considered this as favorable to man.

"But now he sees that Nature will exact her price. He throws smog into the air; Nature flings it back at him. He dumps his wastes into rivers, and Nature refuses to cleanse the waters, as she did back in grandfather's day.

"In contrast, the farmer has long been slapped around by Nature. When he mistreated his soil, Nature fought back. She washed it away, and he ended up tilling subsoil.

"A city man has probably never seen a cow killed by lightning, nor a field of wheat hammered to the ground by hail, nor a forest set ablaze by skyfire.

"But a farmer knows intimately the awesome power that Nature can release.

"The city man has suddenly discovered the Tragedy of the Commons.

"The farmer has known about this principle for centuries. He calls it carrying capacity. An acre of ground will carry only so many cows; a tree can carry only so many apples. When the carrying capacity becomes overloaded, he eases the burden by thinning out. Actually, this is population control. Sometimes man practices it; sometimes Nature does.

"Energy production is the favorite whipping boy for environmentalists. Yet energy is essential in a modern society. Although no one really likes dams, smoky power plants, atomic reactors, or even that old furnace in the basement, we certainly don't intend to saw lumber by hand, nor bathe in cold water in a cold bathroom.

"The question is not which method of producing energy will please the environment. Rather, the question is: Which method insults it least? Hopefully, a comparison of environmental costs of the three sources of electrical power—plus the family furnace and including the flooded valleys, belching stacks, warm shad, and tank farms—will show the best way for obtaining our energy needs while harming the environment least."

DURING the 10 years that *Agricultural Science Review* flourished as a USDA science journal, probably no article brought more editorial satisfaction and reader interest than John F. Fulkerson's and John M. Barnes' "Colloquy on Corn Blight," which

was published in Volume 8, Number 4, 1970. One of the main reasons for its high status was, undoubtedly, the fact that the "colloquy" was an almost verbatim transcript of a taped session between the editor and authors. Just prior to the transcript reprinted here, the editor had asked them if there were any plant pathologists who subscribe to the doomsday viewpoint about blights and other mass disturbances in Nature.

Fulkerson: Yes, there are those who say that we will see more outbreaks in the form of other races.

Barnes: Particularly after reading E. C. Large's, *The Advance of the Fungi*. Pathologists who go back and read this book often intensify their feelings about the advances of fungal diseases.

Fulkerson: I might mention also that even after resistance was achieved in late blight of potatoes, new races came in that were more virulent than the early ones. To say that such a condition is upon us now is not consonant with the facts of the minute.

Barnes: We are confident that in the following months reason will take over as it did in other emergencies. Time has a way of bringing together more reason—as more facts come in. We have had other outbreaks and will continue to have them in a dynamic system.

Man, because he is working in a modern context of science, has no real reason to say that, because we are working in sophisticated times, we should disregard the annals describing worship of Rubigus or the migration from Ireland in the last century. We have seen epidemics before, and we have every reason to expect that we will have other epidemics in other forms or in other crops.

Fulkerson: Even without epidemics, which are a flamboyant example of nature out of balance, it is hard to be patient with the extreme ecological rhetoric about the *delicate* balance of nature. In a very real sense, biochemical evolution and the resulting behavioral aspects force one to sense that there has never been a delicate balance in nature—or in our ecology, broadly speaking. Man wants to view things this way because of the belief that, since God placed everything there, all the elements must be in a state of balance. Ecology capitalizes on this outlook on life.

But rather than a delicate balance, a case can be made that it's an absolute nightmare to the creatures of, say, Monterey Bay. When man looks at

this scene, he enjoys seeing the gulls and seals in their so-called balance. If you go to a quiet pond someplace at night to fish, you may hear a raccoon catch a big bull frog on the shore. When you hear that frog scream, you know there is no delicate balance of nature; it's a terrifying war at all times!

This is an age-old conflict. But it ought to be recognized that, in one sense, this concept of a delicate balance of nature is almost a complete denial of biochemical evolution.

I believe we will always have these situations that plague man—such as plant epidemics. This does not mean we cannot cope with them. In fact there are better ways of coping with these situations than we've done in the past.

Barnes: We say smugly that we have learned our lessons from the pages of history—the potato blight, the chestnut blight, and others—and I wonder if we really have. Race T of the southern corn leaf blight fungus was discovered in the Philippines in 1963. In hindsight, should we have launched meaningful efforts to evaluate the potential of transporting southern corn leaf blight into the major corn-growing areas of the world? Did it arise *de novo* in the United States? Is there something out of balance in our views of the dynamics of today's world? But—if we accept the idea that southern corn leaf blight did move from the Philippines—or from the Caribbean—then we did not do a very good job of restricting its movement.

OUR final selection comes from the piece by *Review's* founder, T. C. Byerly, titled, "Beyond the Frontiers," in which he jotted down some bits and pieces of philosophy gleaned from his 40-odd years of service as a teacher, scientist, and administrator. It was published in Volume 10, Number 1, 1972.

"Traditionally, science in the United States has kept its adversary content at a safe, low visibility level. A doctorate candidate was required to defend his thesis in his oral examination. But as the production of Ph. D's increased and popular professors turned out candidates with whom they were less than intimately acquainted, that defense became rather indifferent and perfunctory.

"Even at this point, the adversary content remained low. Indeed, the very quantity of scientific output defied criticism. Nuclear physics and the concomitant bomb had filled the world with awe.

War would be no more, people believed, because no nation would dare risk extinction. DDT had saved millions from plague and malaria. Science could do anything!

"A few critics, however, began to speak out. Their ranks multiplied. Those who believed science could, indeed, do awesome things shouted that it should be curbed. Those who believed that the indirect effects of science were mostly evil—even when primary effects were ostensibly good—joined them.

"On a more serious note, youth looked at the material products of science-based technology and became bored with them. Science had produced nothing that seemed important to them. And so they retreated, in disturbing numbers, to a world of sensual perception, sensitivity, and hallucinations.

"Should we apply technology as soon as the direct benefits are demonstrated to exceed its direct costs?

"Or, to state it another way, should all indirect costs—and benefits—first be demonstrated before technology is put to use? We are moving in the latter direction, but here we face probability again. Many indirect effects, both beneficial and adverse, are likely to be discovered *only* when technology is applied. The British physicist, John Tyndall, had something to say along this line; we might do well to bear it in mind:

"'To look at his picture as a whole, a painter requires distance; and to judge the whole scientific achievement of any age, the standpoint of a succeeding age is desirable.'

"Plato said: 'There are three acts which are concerned with all things; one which uses, another which makes, a third which imitates them.'

"In science, there is a long-fixed tradition that priority of discovery is the highest achievement of scientists. This tradition becomes more and more obscured by the development of teams of scientists making multidisciplinary attacks on a single problem.

"Devices for assignment of credit vary widely. Some senior scientists, major professors, for example, refuse to have their name on a paper when the actual work was done by junior scientists or graduate students. Others always insist on being the senior author. More frequently, grants are made to senior scientists who provide umbrella support for a flock of junior scientists or graduate students.

"This problem, a phase of the general problem of plagiarism, reminds me of Montaigne who dealt with that topic with desperate dicta: 'The bees pillage the flowers here and there, but they make honey of them which is all their own.'

"How may one reconcile the proprietary value of ideas—apparent products of the human mind—with the cult of objectivity which requires their evaluation wholly apart from their authorship?

"Data from every source may be synthesized redundantly with fresh lots. This exercise is often less fruitful than a fresh start, discarding all the data of the past, obtaining fresh, relevant, and adequate data to test the hypothesis at hand. Waiting until after the fact may sometimes be soon enough to compare a current finding with the past. But we do often innocently, ignorantly, fruitlessly rediscover things long known."

Integration of Systems Science Methodology And Scientific Research

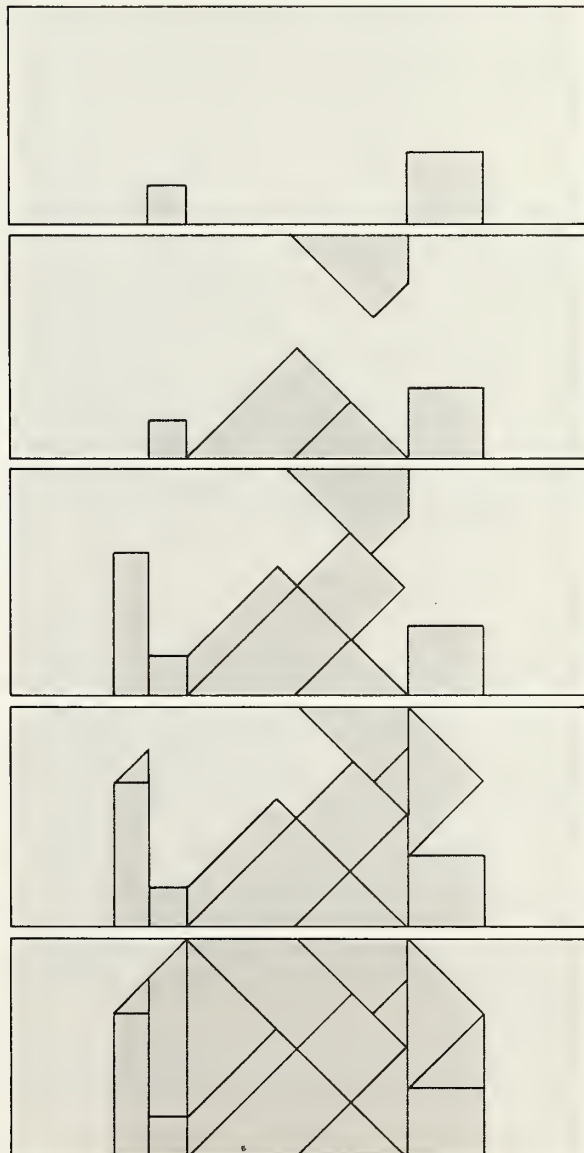
JOHN A. WITZ

SYSTEMS science, a new and unique discipline, has grown out of man's attempt to study and control larger, more complex systems than has been possible in the past. The NASA moon exploration program is a vivid example of the application of the systems approach to the management, research, design, development, and operation of a large hardware system. Although hardware, especially military hardware, systems have received the most publicity for developing and using systems techniques, these methods are finding their way into a widening variety of problem areas.

Among the fundamental principles of the systems philosophy are consideration of the complete picture and inclusion of all relevant elements which influence a decision or response in a particular study. New techniques have been developed to organize and represent large numbers of variables and study their interaction and feedback in a system. Some people, in fact, visualize systems science as being simply the collection of all such analytic tools and methodology.

The multidiscipline approach is also basic to systems philosophy, because the specialized knowledge of a myriad of details needed to carry out a typical system study cannot usually be found in one person nor one discipline. Moreover, the methodology which makes up the system repertoire originates from a variety of recognized disciplines. On this basis, systems science might be termed a "meta-discipline."

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Systems engineering, from which systems science has developed as a generalized extension, is the study of large hardware systems. These systems need to be designed and built and do not, therefore, exist *a priori*. On the other hand, the systems under study in scientific research, especially in the life sciences, are normally in existence. Controlled experimentation with the system is often possible. Both situations require the search for a meaningful description of how a large, complex system is organized and operates, suggesting that many of the analytical techniques can be directly transferred. Major differences in philosophy also exist, though, and the transfer may not be straightforward.

Recent critical reviews have described a number of systems studies that have not lived up to the great expectations and claims made for them (7).¹ Although such accusations may be partially true, in most cases, bad application of systems analysis rather than inappropriateness of systems analysis was involved. Separating the difference between a tool and the application of that tool is important (3). Introducing the use of the systems approach does not mean one can do away with the need for good management, good scientific research, or, in general, good thinking. The application of these modern tools still requires the same careful selection and usage as the analytic tools of the past—perhaps even more so because of the increased complexity of the problems being attacked.

Generalized Systems Methods

THE “elements” of a system include (a) system boundary; (b) function or purpose; (c) external environment, inputs, and outputs; (d) equipment; (e) human intervention; (f) information catalysts; (g) internal operation, sequences, interactions, and feedback. Each system element must be defined in terms of physical attributes, dynamic attributes, conditions for existence, controllability, and interface (17). Good system definition is important, not only for application of most systems methodology, but for proper direction and coordination of research.

Basic to the system definition process is the theory of system hierarchy. A main tenet of this theory

is that every system is composed of subsystems which in turn are composed of subsystems themselves. The goal in using the hierarchical approach is to define the various subsystems independent of one another so that each may be studied individually and the results combined. This requires careful analysis of feedback and interaction within a system to make sure all subsystem inputs and outputs are properly defined.

The various levels of a hierarchical structure must be determined from the current knowledge available for a given system. Beyond the cause-effect relationships of defined system variables, the important factor in determining subsystem levels is the natural frequencies, cycle times, or relaxation times exhibited by the processes within the system. An animal or plant, for example, may be subdivided into the basic physiologic processes, which in turn are composed of various organs and components. Each organ may be studied from the cellular level, then the biochemical level, and possibly down to the molecular and atomic levels. In application, only those levels necessary to a particular study need be defined; processes under study at a given level are normally explained in terms of theory at only one or two levels below. Thus, one researcher’s “microsystem” is another’s “macrosystem.”

Research in general, and the systems approach in particular, are typically carried out by cycling through two activities—analysis and synthesis, either of which may be qualitative or quantitative, depending on the particular phase of study being conducted. The two terms, analysis and synthesis, are used in a general sense here, meaning “to loosen or separate” and “to place with or combine,” respectively (5). In the qualitative definition of a system, for example, analysis includes identifying the individual system elements defined above. Through synthesis, then, the elements are placed in some ordered manner that depicts the whole system. This may be carried out in words or through the use of diagrams. In a quantitative phase of study, analysis determines the functional relationships between system elements; synthesis combines these relationships into a viable, useful format.

In either the qualitative or quantitative phases of study, results of the analysis-synthesis cycle can be termed a model. Many people consider modeling to be synonymous with the systems approach; how-

¹ Italic numbers in parentheses refer to Literature Cited, p. 47.

ever, in this general connotation, it is a definite part of any research.

The intention and the result of a scientific inquiry is to obtain an understanding and a control of some part of the universe. No substantial part of the universe is so simple that it can be grasped and controlled without abstraction. Abstraction consists in replacing the part of the universe under consideration by a model of similar but simpler structure. Models, formal or intellectual on one hand, or material on the other, are thus a central necessity of scientific procedure (19).

Krigman (10) defines the general notion of a model as follows:

Models are icons * * * with inherent parameters resembling those of real or imaginary prototypes. Associated with each model are symbols representing significant elements of the original, rules governing relations between symbols and defining operations to be performed, and conventions for interpreting observations and results of manipulations.

The utility of models lies in simplifying real phenomena, to a form better known or more easily comprehended. Modeling is used * * * when operations on prototypes are impossible, for example, if a system is proposed but does not yet exist or if a phenomenon is being hypothesized. The most promising models, according to Max Black, are those with implications rich enough to suggest new hypotheses and speculations relative to originals.

Krigman continues on the various types of models:

Physical models essentially rely on material objects or systems, and are therefore subject to real constraints which guarantee some degree of self-consistency. Functional models are more abstract, and correspondingly less encumbered by accidental properties.

The most apparent physical models are those which reproduce the form of the original * * * scaled in some convenient way. The validity usually depends on maintaining a form of ratiometric similitude with the original. Instrumental or analog models are also physical. These involve representations using substitute media, which reproduce the structural relations inherent in the prototype.

In graphical, mathematical, and digital simulation models, objects or thoughts are projected onto a domain of abstract symbols and conventions. These models are basically functional, although, constraints may be imposed in the rules of formulation which add physical effects. The technique offers precision, ease of inference, and relatively straightforward application of rules as substitutes for physical operations.

As the complexity and scope of the system under study increase, development of physical models becomes increasingly difficult and functional models must be relied upon. The goal in the mathematical analysis of functional models is the derivation of explicit descriptions for the elements or phenomena of interest. When such analysis is impossible, an alternative technique, simulation, can become useful.

A digital simulation model is an algorithmic form of the system model, programmed for a computer to calculate the functional relationships at successive instants of time, thus generating a time series of values for each model variable. The simulation approach does not directly provide mathematical solutions, rather it allows experimentation with a model in much the same sense as one experiments with a real world system. Experiments, defined through the inputs and initial conditions of the model, can be based on historical data or may represent situations which are difficult or impossible to achieve in the real world.

Models thus can provide an extension of a researcher's power for handling complexity, a framework for collecting numerous bits and pieces of information, and a tool to evaluate and experiment with a system and demonstrate new ideas or hypotheses. Moreover, a proven model can be further applied in a predictive mode to improve or optimize the control or use of the modeled real world system.

Krigman (10) adds a caution regarding models, " * * * risks are high of confusing mathematical precision with strength of empirical verification, by forgetting that results are not explanations of phenomena but only consequences of assumptions." He also mentions Maxwell's warning that "observing a phenomena through an analogous medium encouraged 'blindness to facts and rashness of assumption.'" These two warnings are well to remember.

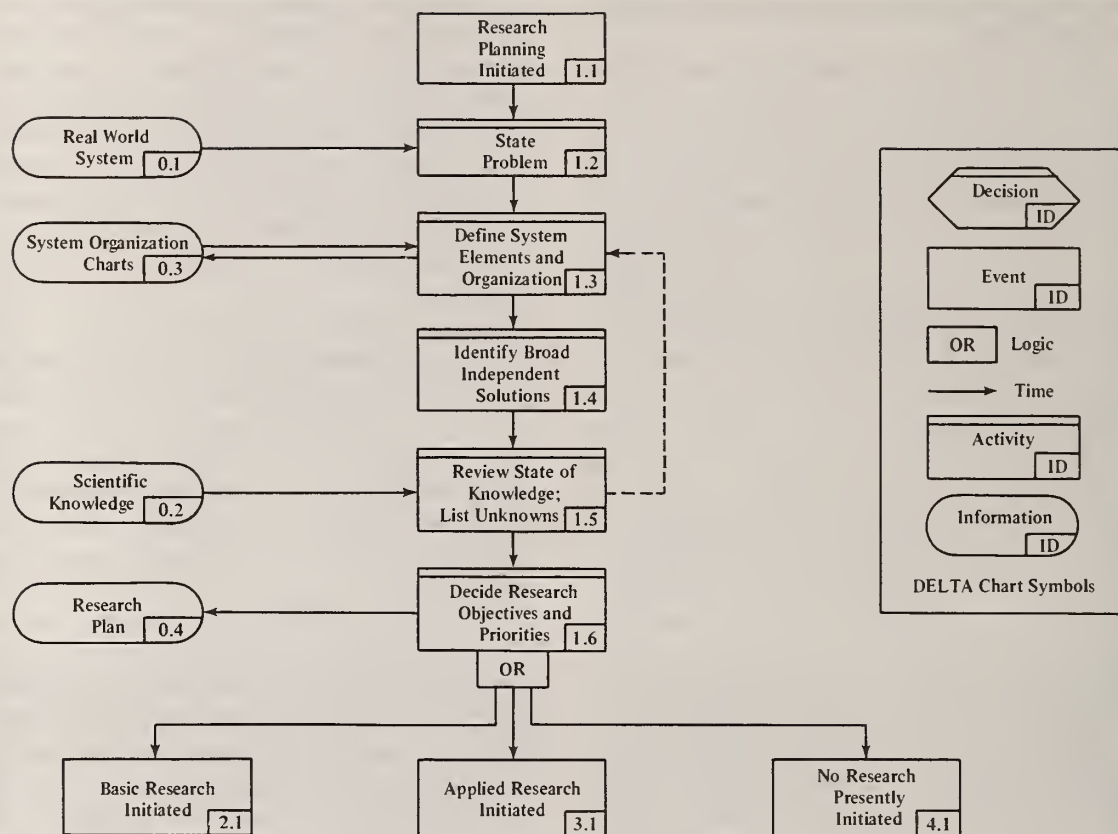


Figure 1.—DELTA Chart of Research Planning

Although the theory and use of models has advanced greatly, there still remains the crucial need for intelligent thinking in the making of hypotheses and the construction of models, and for adequately validating models once they are designed.

A Model for Integrating Systems Methods and Scientific Research

Research Planning.—The model for integrating systems science techniques and scientific research will be divided into three major submodels, the first being research planning. The planning model, adapted from a research planning procedure developed by Vanden Berg (22), is shown in Figure 1 in the form of a DELTA chart. (The DELTA chart block shapes, defined in the inset of the figure, have been adapted from Warfield and Hill, 23.)

Planning begins with a statement of a problem that exists in the real world for which a solution does not appear to be directly available. The problem statement establishes the scope and nature of all the steps to follow and is, therefore, an important first step. It is difficult to establish a standard format for problem statements useful at all levels of planning. One format, which has worked successfully at a fairly broad level, implies the objective which cannot be achieved. The implication is attained through specifically stating why the objective cannot be achieved in the form "cause-effects-objective." This approach does not limit the method of solution, nor does it even suggest that specific control of the cause will be necessary.

The second step (block 1.3) is to carry out a qualitative study of the system, defining all important system elements and assembling them in an organized manner as described in the previous sec-

tion. The documentation of this study has been labeled "system organization charts," and the qualitative model inherent in this documentation forms the basis of communications about the system for the remainder of the planning and research program. During the definition of any system, it is also important to keep the hierarchical structure of the definition in proper perspective. One approach is to orientate the primary system being studied in the next larger system. All inputs and outputs should then be checked to verify that a logical, consistent, and independent system has been defined. This same procedure can then be followed downward through the hierarchy with each subsystem defined.

The next step (block 1.4) is to identify broad independent solutions to the problem stated in the first step. The qualitative model of the system now provides a means of properly describing and interrelating the various independent solutions. The process of defining a system can, itself, often lead to a number of solutions. This portion of planning calls for "brainstorming" without consideration of practicality, feasibility, or for combinations of various independent solutions. Issues such as these are dealt with in later steps.

The heart of research planning is identifying what knowledge must be obtained to implement each of the independent solutions. This is carried out by listing for each independent solution the fewest independent questions, which, if answered, will allow the application of the corresponding solution. The broad independent questions can usually be broken down into small subquestions, each of which may then be further broken down, forming a "research question tree." The final questions must provide sufficient detail to suggest the difficulty of solution and allow identification of the specific research disciplines involved. The questions normally relate directly to the qualitative model as, for example, unknown functional relationships between system variables. Often at this point an inconsistency will appear between the questions generated and the system model as defined. If may be necessary, therefore, to cycle back as indicated by the dashed line on the figure, and adjust or improve the model accordingly.

For each question tree developed, typically a dichotomy exists: either (1) additional basic knowledge is needed to solve the problem or (2) applica-

tion and development of current knowledge is required. (A third possibility could exist such that no research is needed. If a problem is found to be readily solvable, no research need be planned." In most situations, all possibilities may occur for separate subproblems. Thus, a research plan must be developed to order the subproblems and establish priorities (block 1.6). Generally, research plans rank the unknowns in their order of importance through the use of cost/benefit ratios or similar criteria.

When basic knowledge is needed, answers to the unknown questions take the form of hypothesized explanations which can be verified by experiments. When the necessary knowledge exists but its application is in question, proposed answers take the form of hypothesized control strategies and measures of performance. This distinction provides a useful definition of basic research (the former situation) and applied research (the latter situation).

Basic Research.—The classical scientific method which has evolved over the past three centuries outlines a systematic approach for carrying out scientific research. The generally accepted pattern is to (1) define the problem, (2) formulate alternative hypotheses, (3) design experiments to disprove the hypotheses, (4) perform the experiments, (5) test the hypotheses, adopting the one that remains, and (6) publish the results or recycle the procedure or both. Figure 2 is a DELTA chart showing the possible integration of systems methods into this pattern of basic scientific research with particular emphasis on modeling. The inclusion of the tools and techniques of systems science does not involve any great modification of this recognized and tested procedure, but actually stresses its step-by-step application.

The first three activities shown carry over directly from research planning. First, the objectives of the project, as derived from the research plan, are established (block 2.2). Beginning with the results of the planning phase, a more detailed qualitative analysis will usually need to be made to define the particular system to be studied (block 2.3). Then, based on the research plan and the system definition, the specific researchable questions to be answered are identified (block 2.4). These questions if complete, indicate on a one-to-one basis the hypotheses required.

The classical hypothesis makes a statement for which a true-false answer is sought. A typical hy-

pothesis thus would state the existence of some phenomena or specify that two variables were related. However, in the study of system elements such as internal operation, interaction, and feedback, more information is needed than simply whether a relationship exists or not—the actual functional relation, if existent, is required. Consequently, hypotheses must be more inclusive in their descriptions than has been usual in the past.

The formulation of hypotheses (block 2.5) and the construction of a model (block 2.6) are very closely related, thus the terminology “hypothesis model.” The modeling activity forces the researcher to describe in detail exactly how he thinks or hypothesizes the system operates. As indicated in the figure, existing models and scientific data form the basis for the modeling effort.

Once a researcher has a model constructed and he has verified that it performs correctly—that is to say, the model is an accurate description of his hypotheses—the model can be put to work. This is the simulation phase of *simular*¹ research that is not possible unless modeling is used. Various experiments to prove or disprove the hypotheses can be defined and then tested through simulation (blocks 2.7 and 2.8). Key measurement variables can be identified through sensitivity analysis, levels of control variables can be selected for optimum experimental design, and the expected results can be tabulated by using a quantitative model. Larger, more complex, yet at the same time more efficient real world experiments can be designed in this manner.

Since experiments on a model can usually be conducted more quickly and at less cost than real world experiments, more rapid progress can often be made by studying a hypothesis model. If the real world system is highly complex, extremely difficult to control in a laboratory, or extremely costly to test, real world experiments may not be possible. In such situations either a model is used or else man proceeds with considerable uncertainty.

If a quantitative model is not used, the research must proceed directly from formulating hypotheses to designing experiments, to the real world. Any chance of testing or improving the experiments is

thus eliminated. In cases where a model cannot be readily constructed, the attempt at modeling often identifies key problem areas and offers new insight into the system under study that would not otherwise be discovered.

In the biologic sciences, as the study of life processes continues, there will be a greater demand for controlled environment experiments having a large number of variables under control to test multiple hypotheses. Models should be extremely valuable in dealing with these complex situations. More complicated experiments in the natural environment will also be needed, especially for final validation of models. The systems and modeling approach thus will not replace, rather enhance the needed top-quality scientific endeavor.

The goal of real world experiments is to provide data sufficient to prove or disprove the hypotheses. In modeling terminology, this represents validation of a model (block 2.10). The test for model validation asks the question “are we satisfied?” and this test becomes an important measure of when to stop doing research. If we are not satisfied, we return and review our definition of the system and our hypotheses and construct a new model. However, if we feel that the current model meets the present requirements of precision, relative to the priorities for knowledge in other systems, we then have reached a point where we can close out work on this particular system. If real world experimentation is not possible, validation must be based on other criteria or on intuition.

The picture of basic research presented in this section is conceptual and does not indicate the many smaller feedback loops and variations for particular circumstances which might be expected. The basic outline in each case, however, remains that of the time-tested scientific method. In the study of large systems, models for the various subsystems may be developed individually, and then combined to form the complete model. Levels of satisfaction with the complete model, in this case, are generally reached in steps, as the various submodels are improved to a common level of precision.

To form the basis for future research or for applied research on the same system, a model must be documented and cataloged. If proper documentation is maintained during model development, intermediate “versions” of a model can be put to limited

¹ *Simular*, adj., having to do with simulation as defined in *A Glossary of Simulation Terminology* (13).

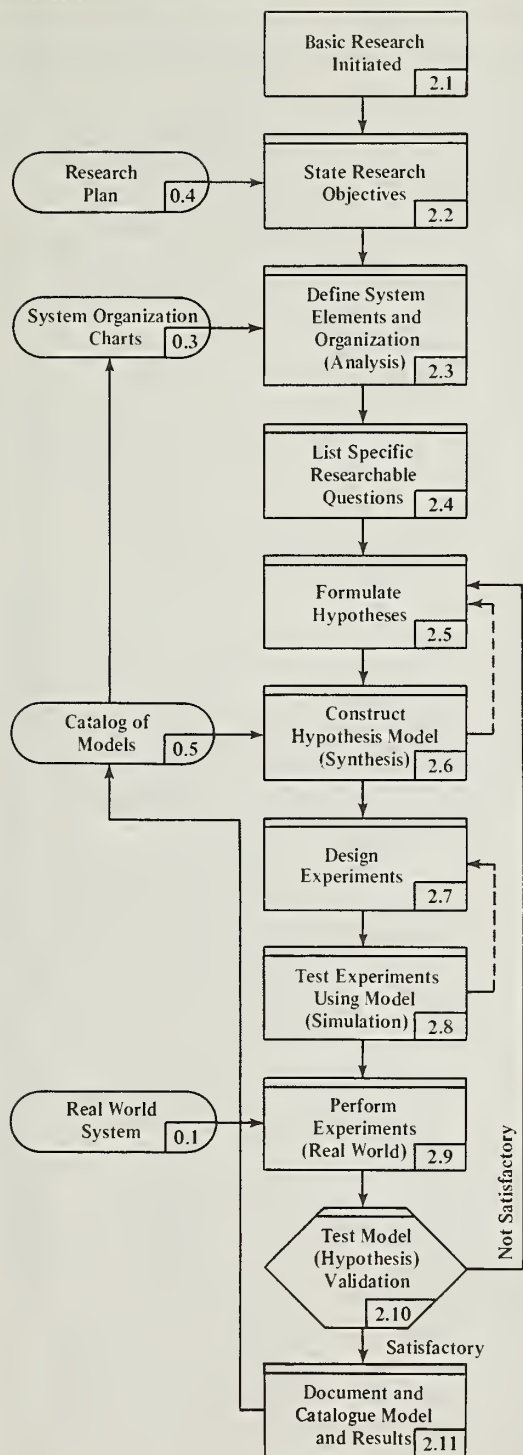


Figure 2.—DELTA Chart of Basic Research

use by other scientific "users," allowing independent study and validation of the model. The documentation of a model programed for a computer includes descriptions of the theory, hypotheses, and assumptions; the computational methods and techniques; validation attempts and results; and any applications made. Also required is a user's manual which describes how to prepare and execute the programed model and how to interpret the results.

Applied Research—While the goal of basic research is the extension of scientific knowledge, applied and developmental research is concerned more directly with control of the real world system. In this type of research, a systematic approach again can be defined, as shown in figure 3. The research objectives and systems analysis blocks are present as before, based on the outputs of the research planning phase.

In applied research, the system model becomes an important tool for performance evaluation. The first important step in using this tool is the definition of a measure of system performance. This step requires the researcher to quantify what is desired of the system and what costs will be incurred in controlling the system in order to realize the desired performance. Performance is often thought of in terms of economic factors such as profit functions, but in more general systems studies, non-economic functions are often defined. It is also necessary to define quantitatively the control strategy to be studied. These two blocks, definition of performance and control strategy, are analogous to the definition of hypotheses in basic research.

The construction of a performance evaluation model is based on the current basic knowledge of the system, hopefully obtained in the form of a catalogued model or models. Validated models from basic research can be directly applied in the development of an evaluation model although some modification is usually necessary due to the requirement for greater computational efficiency. The desired control strategy and calculation of the measure of performance must also be included in the evaluation model.

Through predictive simulation, then, the desired optimum or suboptimum response can theoretically be found and the necessary control levels determined. If a model is not constructed, simulation studies cannot be conducted and activities 3.6 and

3.7 in figure 3 must be omitted. However, just as in basic research, development and testing of control strategies can often be done cheaper and faster on a model than on a real world system. Based on *similar* research, experimental or prototype systems can then be developed and evaluated (blocks 3.8 and 3.9). These steps are directly analogous to the experimental and validation steps of basic research. The results can be expected to be either satisfactory or not satisfactory, as the case might be. If satisfactory, the control strategy can be implemented into the real world system; if not, further investigation will be called for, as indicated by the feedback loop in the figure.

A number of systems engineers today feel that not enough emphasis is placed on the problems of implementation. In the outline presented for applied research, implementation should be included in the definition of system performance (block 3.4), as part of the cost of controlling the system, and implementation feasibility should be considered when formulating the control strategy (block 3.5). Research purported to be developmental is often carried out with no hope of actual implementation. Such research belongs in the category of basic research and its worth measured on the basis of its contribution to scientific knowledge.

Analysis of the Integration Model

THE essence of integrating systems methods and scientific research results from modeling. It is specifically identified in five of the activity blocks of figures 1, 2, and 3—qualitative models in blocks 1.3, 2.3, and 3.3 and quantitative models in 2.5 and 3.6. No quantitative model was identified in the planning phase; however, such modeling could be used in activity 1.6. For example, if a model of a commodity industry existed or could be developed, the benefits to the industry from changing various parts of its technologies could be evaluated. Such information would be valuable in establishing research priorities.

It is difficult to conceive that a single research method or approach would be applicable to all possible projects. Thus, variations and modifications are to be expected in the conceptual pictures of research and research planning that have been presented. In the same manner, not all research prob-

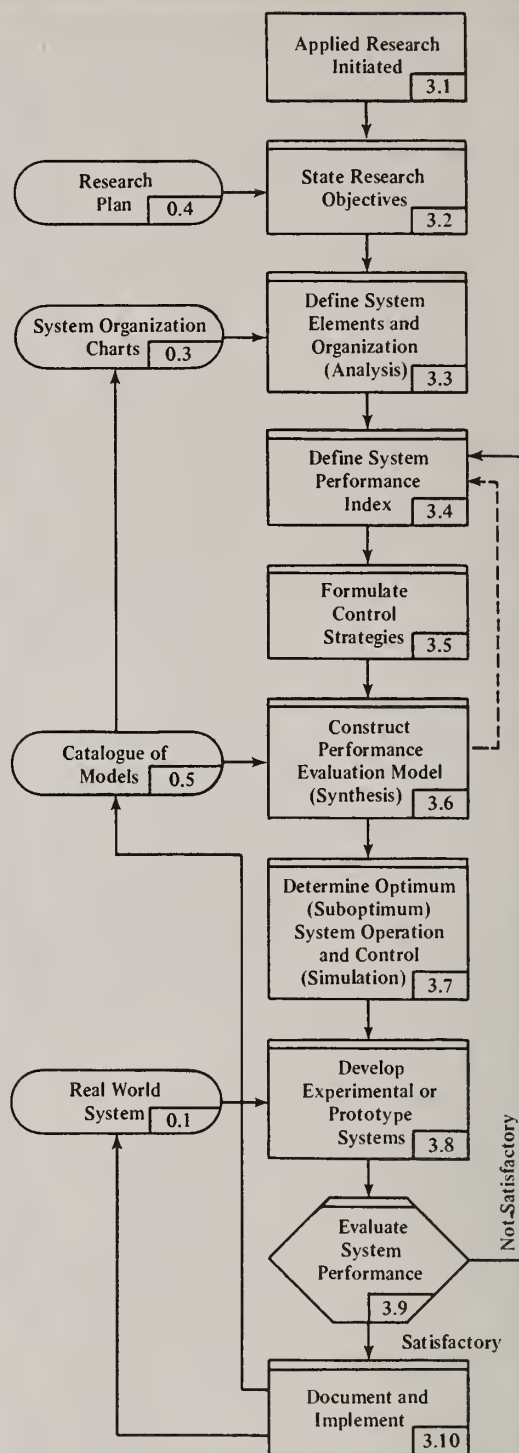


Figure 3.—DELTA Chart of Applied (and Developmental) Research

lems lend themselves directly to the development of a large quantitative model, at least at this point in the state of the modeling art. It should be remembered, however, that basic research is the search for an explanatory model of one form or another.

Integrating modeling and scientific research requires an appreciation of the hierarchical concept of systems and models. An economic study of plant or animal production, for example, requires a model which relates the commodity to the overall economy. On the other hand, the study of some subsystem such as plant photosynthesis or animal heat regulation requires a completely different model. The difference is not one of precision or accuracy but that of hierarchical level. As mentioned earlier in this paper, processes at any level are normally explained in terms of theory at one or two levels below. This strategy is not necessarily one of choice, but appears to be a basic limitation of man and his current ability for analysis (25).

In view of this limitation on analysis and modeling, the overall goal of research should not be to construct one gigantic, complete model of a system and all of its subsystems, but instead an integrated program of modeling research. The importance of research planning for organizing and coordinating such a program now becomes evident. The qualitative descriptions of a system, referred to in the figures as "systems organization charts" are proposed as one way to coordinate the models so that each modeler can relate his efforts to the other. Model documentation and the "catalogue of models" is another important aspect of communication.

In the past, most modeling efforts started from scratch, and they have been quite personalized, incorporating considerable art form. An argument can be made in favor of this approach since the modeler gains invaluable knowledge about the system which he would not otherwise. A limit exists, however, as to how far one person can progress, starting from the same point each time. Thus, this argument must lose value if we are to expect optimum advance in knowledge. We must be looking towards building upon what has been learned and modeled in the past (12).

The model can form an important basis for interdisciplinary communications. An important requirement to transmit this communication is uniform methods of documentation and cataloging of vali-

dated models. Some of the present techniques seem to break down with the large, complex models being developed today. Many modelers in the biological and agricultural sciences feel that this is a significant weak link in today's modeling efforts. While it can be argued that a scientist or modeler is just too jealous of his time to document, it can also be argued that top research personnel should not be tied up with the busywork of documentation. The answers to who should document and how are not readily in hand at this time. New methods or approaches will need to be developed.

A catalogue of models (block 0.5) refers to an organized collection of models in a form readily applied by a user—someone who can use a model but was not necessarily involved in its development. Most hypothesis models are not readily usable in the direct form in which they were developed. The interface between the user and the model needs special attention if models are to be accepted and applied by the scientific community. The "chicken or the egg—which came first" problem arises here. Some see no need for a catalogue as there is no proven demand; yet, there will probably be no demand until models that are more user-oriented become available.

Use of the computer creates special problems in cataloging models. In addition to extra documentation, as defined in the earlier section on basic research, extra programming effort is usually needed. With a newly developed hypothesis model, housecleaning may be required to eliminate any unnecessary calculations generated in the development process, algorithms can be modified to optimize execution time, and additional programming can be added to arrange execution control and the input-output of data for user convenience. In some cases, special programming may be needed to facilitate execution from remote time-sharing terminals. If a system exists for which several subsystem models have been developed, it may be desirable to combine the existing models into a compatible package. Single, higher level models of the overall system can also be derived from existing subsystem models for use in research at broader levels in the hierarchy.

Contributing to the programming problem is the variety of computers being used and the large number of languages available for these computers.

Progress in standardization has been made, one way or another, in the last few years, easing this particular problem. Nearly identical dynamic simulation languages, for example, are available for most machines. Special attention will continue to be needed to assure that the necessary computing power and matching software is readily available to the researcher.

Because of the close tie between hypothesis definition, the model, experimental design, and actual experimentation, the need for the scientist to remain in close contact with the model is imperative. As Kowal (9) puts it, "the intelligent use of models requires explicit connection of measurements and concepts." It is never satisfactory to "accumulate measurements, yielding endless statistics and descriptions, with few connections to concepts," nor to "construct elaborate models, never connecting them to the real world. Ideally, the scientist should work both ends simultaneously." Walt Whitman put in quite succinctly—"Theory without fact equals fantasy; fact without theory equals chaos."

In discussing pitfalls in the systems approach, Ronningen (18) says "one of the most serious is the failure to differentiate between a system-design endeavor and a pure research endeavor. If some of the components in the mathematical model have not been thoroughly explored by conventional research, the systems-design team runs the risk of converting questionable inputs into questionable outputs." What is missing here is not the need for differentiation, but a need for closer liaison between conventional research and a system-design endeavor which is the basis of this paper. The above problem can be avoided in three ways: (a) careful review of the state of knowledge in the research planning phase, (b) careful validation of models in the basic research phase, and (c) the use of properly validated models in the applied research phase.

Ronningen continues, "another risk—particularly when the proposed system is extremely complicated and requires the use of highly sophisticated mathematical models—is that attention can be diverted from the substance of the problem to the mechanics of the analysis." Here, the importance of a balanced team is shown. If the team has one member to handle the myriad of computation details, the remaining members can more fully concentrate on the overall system and the defined research problem.

The multidiscipline team can present problems also. For example, some people see the systems analyst or modeler in a lofty position above the level of normal scientific research; others view the scientist as an architect and the analyst as a draftsman. However, most successful projects are the culmination of balanced teamwork, requiring a mutual respect for the differing abilities and knowledge available from alternate disciplines.

Given the proper cooperative spirit, the major interdisciplinary barriers involve the transfer of information (6). In the most simple case, a single person learns the necessary knowledge to work in a second discipline. Generally, this limits the depth of knowledge on any one subject; and it is from this basis that today's emphasis on multidiscipline or interdisciplinary teamwork stems. Increasingly, the modern biology and agriculture student is being made aware of the systems and simulation approach. With careful attention to the communicative abilities of a model and with specialized programming support, many current scientists could also become active members of a *similar* research team.

As was mentioned earlier, not all research can make immediate use of systems science tools in the current state-of-the-art. It is important, meanwhile, that scientists recognize the importance of the systematic application of the scientific method. While a detailed quantitative model is not always necessary, a good statement of the hypothesis is. Additionally, all scientists should be able to provide important inputs into the research planning phase, especially with respect to the current scientific knowledge.

The documentation and cataloging problem suggests the need for a group on a national basis to provide specialized services for documentation and programming. A major hurdle with this sort of arrangement, though, would be communication about the model from the researchers to the documentation personnel. What may be missing in *similar* research, which is present in other experimental work, is the technician. A systems or modeling technician could provide the missing link in both programming and documentation support for the simulation project. As part of the project team, the technician could maintain the proper documentation throughout the project, allowing the research to be carried out more efficiently and accurately.

Today, such a person with the proper training is probably not available at the technician level, so "technician" may be the wrong terminology. The necessary background of higher mathematics and specialized computer application would most likely be found at the bachelor of science level in today's educational scheme. The "simular engineer" would provide additional capabilities to a research project for systems analysis, model development, and experimental design. In the future, it may be possible to define an educational program specifically for simulation at the associate level.

With such support on each project, the national group could then provide indirect assistance through documentation and programing standards, specializing programing assistance, plus providing a central collection point for the catalogue of models, and possibly a current simulation information system similar to the Current Research Information System of the U.S. Department of Agriculture (21).

Summary

THIS paper has discussed a means to integrate systems science techniques into a program of scientific research and development. The approach presented is based heavily on the classical scientific method. The use of modeling was stressed and the modeling concept was used to differentiate between basic and applied research, the former being the design and validation of a model and the latter being the application of a validated model for performance evaluation. Simulation was presented as a way to help improve the efficiency of the real world experiments.

As a part of the total research picture, a systematic method of research planning was included. A technique such as this is applicable to all research, regardless of the level of modeling proposed; yet the outputs are specifically attuned to the organiza-

tion and management of a complex modeling project. The basic method could be used at all levels in the planning hierarchy, from national scope to individual project basis. With proper development, the qualitative system descriptions mentioned could provide the communications link between the various levels.

A key concept with regard to present and future systems and modeling activity is that of communication. The need for an organizational unit on a national basis was suggested to act as a centralized collection point for model documentation and exchange. National activity might also include continued development of improved management and research information systems, including both qualitative and quantitative models.

The proposed integration model emphasized modeling as a tool for research and not as a separate entity in itself. For scientists to properly use this tool, careful selection of multidisciplinary research teams will be required, including the necessary modeling and programing technical assistance. As a number of subsystem models become adequately developed and validated, certain research teams in the future may become involved almost entirely with the combination of these submodels into larger and more general system models. Although the accent will be heavily in favor of computer programing in such groups, their research would still follow the basic outline presented.

With regard to the question of introducing these techniques into new areas, we do not wish for an effort to push formal model development into every research project; on the contrary, it is probably more important at this time to build quality in the *simular* research underway. The exchange and use of available models in current research should receive special attention. New projects can be developed with tools in mind for application if warranted.

LITERATURE CITED

- (1) ANDERSON, P. W.
1972. MORE IS DIFFERENT. *Science* 177(4047): 393.

- (2) CLYMER, A. BEN.
1969. THE MODELING OF HIERARCHIAL SYSTEMS. Keynote Address, Conf. of Application

- of Continuous System Simulation Languages, San Francisco.
- (3) FROSCH, R. A.
1969. A NEW LOOK AT SYSTEMS ENGINEERING. I.E.E.E. Spectrum, 6 (9): 24.
 - (4) GARFINKEL, D., McLEON, J., PRING, M., AND DiTORE, D.
1972. APPLICATION OF COMPUTER SIMULATION TO RESEARCH IN THE LIFE SCIENCES. Simulation Today (5), Simulation Councils, San Diego (July).
 - (5) HALL, ARTHUR D.
1962. A METHODOLOGY FOR SYSTEMS ENGINEERING. Princeton, D. vanNostrand.
 - (6) HARRISON, ERNEST, JR.
1972. INTERDISCIPLINARY BARRIERS TO THE APPLICATION OF SYSTEMS ENGINEERING. Amer. Jour. Occupational Therapy, 26 (5): 225.
 - (7) HOOS, IDA R.
1972. SYSTEMS ANALYSIS IN PUBLIC POLICY: A CRITIQUE. Berkeley, Univ. Calif. Press.
 - (8) INNIS, G.
1972. SIMULATION OF ILL-DEFINED SYSTEMS: SOME PROBLEMS AND PROGRESS. Simulation Today (9); Simulation 19(6).
 - (9) KOWAL, N. E.
1971. A RATIONALE FOR MODELING DYNAMIC ECOLOGICAL SYSTEMS. In: Systems Analysis and Simulation in Ecology, B. Patten, ed. Vol. 1, New York, Academic Press.
 - (10) KRIGMAN, A.
1972. ICON. Instruments and Control Systems 45 (11): 4.
 - (11) McLEOD, J.
1970. TOWARD UNIFORM DOCUMENTATION—Physbe and 1130 csm. Simulation 14 (5): 215.
 - (12) ———
1973. SIMULATION TODAY—FROM FUZZ TO FACT. Simulation Today (3), San Diego Simulation Councils (Mar.).
 - (13) MIHRAM, G. A.
1971. A GLOSSARY OF SIMULATION TERMINOL-
ogy. Jour. Statistical Comp. Simulation, 1: 35-44.
 - (14) PATTEN, B. C.
1971. SYSTEMS ANALYSIS AND SIMULATION IN ECOLOGY. Vol. 1, New York, Academic Press, Ed.
 - (15) PATTEN, B. C.
1972. A SIMULATION OF SHORTGRASS PRAIRIE ECOSYSTEM. Simulation 19 (6): 177.
 - (16) PLATT, J. R.
1964. STRONG INFERENCE. Science 146 (3642): 347.
 - (17) PRESTON, T. A.
1971. IDEAL FARM SYSTEM DESIGNS: A GUIDE TO FARM RATIONALISATIONS. Edmonton, Alberta; Dept. Agr. Engr., Univ. Alberta, Work Study Bull. 2.
 - (18) RONNINGEN, T. S.
1968. SYSTEMS RESEARCH IN AGRICULTURE. Agrl. Sci. Rev., 6 (4): 1.
 - (19) ROSENBLUETH, A., AND WIENER, N.
1945. THE ROLE OF MODELS IN SCIENCE. Phil. of Science, 12: 316.
 - (20) THIMM, ALFRED L.
1970. GENERAL SYSTEMS THEORY: A TOOL FOR SOCIAL ANALYSIS. Jour. of Systems Management, Oct.: 16.
 - (21) TURNBULL, J.
1967. CURRENT RESEARCH INFORMATION SYSTEM. Agrl. Sci. Rev., 5 (3): 30.
 - (22) VANDEN BERG, G. E.
1972. A SYSTEMATIC METHOD FOR PLANNING RESEARCH. Unpublished paper, Agrl. Engr. Res. Division, USDA-ARS.
 - (23) WARFIELD, J. N., AND HILL, J. D.
1971. THE DELTA CHART: A METHOD FOR R&D PORTRAYAL. I.E.E.E. Trans. EM-18 (4): 132.
 - (24) WILSON, I. G., AND WILSON, M. E.
1970. FROM IDEA TO WORKING MODEL. New York, John Wiley & Sons.
 - (25) DE WIT, C. T.
1969. DYNAMIC CONCEPTS IN BIOLOGY. Proc. IBP/PP Technical Meeting, Trebon.



Genetic Vulnerability of Crops

A WORLDWIDE
PROBLEM OF
RISING CONCERN

DURING the past decade, the genetic resources of major agricultural crops have been markedly declining—particularly in the developing countries. The rising concern over this crucial decline has prompted governments, foundations, and international organizations to place high emphasis on development of a global network for conserving these resources.

U.S. Involvement

CROPS grown in the United States are essentially all imported from other parts of the world. Ever since 1492, settlers from Europe have brought seeds and planting stocks with them to be grown in the New World. Crops of American origin such as corn, potato, peanut, tobacco, upland cotton, beans, lima beans, tomato, squash, and others were imported from Mexico or southwards. Plant introduction has been the life blood of our agriculture from the very beginning.

This article is based on a special report by an ad hoc subcommittee of the Agricultural Research Policy Advisory Committee, titled, "Recommended Actions and Policies for Minimizing the Genetic Vulnerability of Our Major Crops."

Altogether the United States germ plasm holdings are very considerable. The national need for imported germ plasm has long been recognized and seed and plant introduction was established as one of the functions of the Office of the Patent Commissioner from 1836 to 1862. It was among the earliest activities of the Department of Agriculture established in 1862. It was also a hobby of planters, governors, legislators, and prominent individuals in all sections of the country. A more formal recognition of need was established in 1897 when Secretary Wilson designated N. E. Hansen of South Dakota as a plant explorer. This was followed immediately by the establishment of the Seed and Plant Introduction Section of the USDA in 1898. These activities have been continued.

This history of Federal plant introduction and regional new crops research is detailed in a publication entitled "The National Program for Conservation of Crop Germ Plasm" (1971), University of Georgia, Athens. Although the publication deals with only a part of the total national effort, it lists a number of significant accomplishments:

1. Dozens of expeditions overseas for collections.
2. A large volume of material obtained through cooperation and exchange.

3. Introduction of some 400,000 accessions.

4. Establishment of regional plant introduction stations to receive many kinds of plant materials, maintain them in viable condition, and distribute materials to plant breeders.

5. Establishment of the National Seed Storage Laboratory for long term conservation of seed stocks.

6. Close cooperation with the Plant Quarantine Service in an attempt to prevent entry of new races or species of pathogens and pests.

In addition to the activities described in the report, several large working collections of specific crops are maintained by the Department of Agriculture and by various State agricultural experiment stations. Germ plasm maintenance and use programs have been particularly effective under working collection procedures. Private and commercial plant breeders also maintain working collections for their use.

Many plant breeding programs use the germ plasm assembled and maintained in the working collections. United States world collections are being screened for resistance to specific races of pathogens; for broad resistance to disease or disease combinations; for insect resistance; for quality traits such as high protein content, better quality protein, high oil, and better quality oil; and for special purpose characteristics for industrial use, etc. These collections have paid off handsomely many times and have been absolutely indispensable to our plant breeding programs. The investment in germ plasm collections has been one of the most profitable ones in the history of our Nation. The vast productive capacity of United States agriculture is due in large measure to the successful exploitation of imported genetic resources over the years.

Negative Aspects

FOR all that, the present situation is dangerous and deteriorating rapidly. The genetic variability upon which man depends for future breeding programs is being eroded and lost almost everywhere in the world, and we are not taking adequate steps to salvage the material before it disappears. Furthermore, we have lost substantial portions of the germ plasm collections accumulated in the United States in the past and more are being lost every year. Even the priceless collections in the National

Seed Storage Laboratory are in jeopardy. When accessions are lost today, they seldom can be replaced; they are gone forever.

There has never been a long-range national policy on germ plasm assembly. Our collecting has usually been in response to specific crises. After we have suffered an outbreak of a serious disease, we can usually find some funds to send a collector to get material. Hopefully, he will find the necessary resistance. We then wait for the next outbreak before anything more is done. This, at least, has been the historic pattern. We can no longer afford such a casual approach to genetic resources.

The endemic plant resources are drying up in the traditional areas of exploration. There has never been a sustained, integrated, and coordinated national plan for the systematic collection of germ plasm to have it available and on hand when the next epidemic appears. The low priority given to plant germ plasm assembly has led to a dangerous situation.

There has not been a national policy for maintaining genetic resources that have been assembled. Although a very few major collections are being well maintained with an adequate commitment behind the operation, most germ plasm maintenance is being done in a haphazard, uncoordinated, and unsystematic way. Many collections are maintained by individuals with a special interest in the germ plasm of a particular crop. When the individual dies or retires, the collection is lost. This has happened again and again through lack of organization and concern. Maintenance of germ plasm is considered by too many to be a routine effort for technicians and not a research program with prestige.

One can argue that a simple solution is to store the private-interest collections in the National Seed Storage Laboratory until they are needed again. *The fact is that the National Laboratory is also in danger.* It is not performing and cannot perform the functions it was expected to carry out when it was established. Such neglect of an essential resource, the task force believes, is alarming and once again reflects inappropriate priorities.

The lack of a suitable tropical facility has resulted in an inability to perpetuate some important materials and is endangering the maintenance and preventing the use of critical collections. A number

of crops important to U.S. agriculture are of tropical origin and many accessions fail to reproduce in the United States. These include accessions of corn, cotton, sorghum, peanut, beans, pearl millet, and a number of others. Most of the world sorghum collection has been grown in Puerto Rico but facilities are limited even for this crop and the program to convert tropical sorts into types that can be used in the Midwest and South is desperately in need of support. We must depend on cooperation in various parts of Latin America for maintenance of the tropical corns. Facilities for cotton are entirely inadequate, and the exotic peanut collection is threatened by discard. Again, the germ plasm priorities are woefully deficient.

There has never been a directed national effort toward the effective utilization of genetic resources. Our collections have never been used as much as they should have been, partly for want of basic research on patterns of variation, on genetic transfer in wide crosses, on components of adaptation, and on cytoplasm available. Most exotic materials are poorly adapted and must be converted to suitable types before the germ plasm can be used. Limited amounts for supporting research of this kind have been provided but seldom on a sustained and systematic basis.

The national effort has a long way to go to mesh in any significant way with international programs. Gene banks have been established at Braunschweig, Germany; Bari, Italy; Izmir, Turkey; Leningrad, U.S.S.R.; and in Japan, and special collections are maintained at Los Baños, Philippines (rice); El Batán, Mexico (maize) and so on. For safekeeping, it is essential that these holdings be at least duplicated and held in two or more locations.

National Academy Study

FOLLOWING the disastrous southern corn leaf blight epidemic in the United States in 1970, the Agricultural Board of the Division of Biology and Agriculture, National Research Council of the National Academy of Sciences, established a committee to look into the circumstances of the epidemic and to examine the more general issue of whether other major crops are also vulnerable. The study was supported by the Research Corp. of New York and the U.S. Department of Agriculture. A summary of the committee's report appeared in Volume

10 Number 4 of *Agricultural Science Review*, 1972.

In recognition of the significance of this 1972 study and the genetic vulnerability problems, leaders of the U.S. Department of Agriculture and the National Association of State Universities and Land-Grant Colleges established a committee¹ on genetic vulnerability with the charge "to provide a framework of proposed actions and policies within which the agricultural science community can move with vigor to meet its responsibilities to maintain genetic vulnerability."

The National Academy of Sciences study presented in some detail the current status for several of our major food, feed, and fiber crops. The general situation is the same for each crop—current U.S. production rests upon a very restricted genetic base. Five publicly developed and released inbred lines of corn were represented in the parentage of about 70 percent of the seed corn used in 1970. Approximately 40 percent of the hard red winter wheat acreage is planted to two varieties and their related derivatives. Most of the widely grown soybean varieties for the northern area involve the varieties Richland and Mukden in their parentage; 58 percent of the soybeans grown in the Delta area have both AK and Clemson as ancestors. All of the current sorghum hybrids have a common cytoplasmic sterility component. These findings suggest that nearly all of our cultivated crops have such a narrow genetic base as to be highly vulnerable to some new races of a pathogen, new biotype of an insect pest, or severe environmental stress.

Impact on World Food Supply

IN the President's Science Advisory Committee Report on the World Food Problem of 1967, a lag between per-capita food supplies and population

¹ Committee roster: G. F. Sprague, University of Illinois, chairman; W. L. Brown, Pioneer Hi-Bred International, Inc.; B. E. Caldwell, USDA; John Creech, USDA; W. H. Gabelman, University of Wisconsin; J. R. Harlan, University of Illinois; H. J. Hodgson, USDA; R. T. Johnson, Spreckles Division, Amstar Corp.; C. F. Lewis, USDA; John McKelvey, Rockefeller Foundation; H. M. Munger, Cornell University; D. C. Peters, Oklahoma State University; L. P. Reitz, USDA; H. F. Robinson, Purdue University; Paul Sand, USDA; S. G. Stephens, North Carolina State University; S. G. Younkin, Campbell Soup Co.; and D. J. Ward, USDA.

growth was projected. The "Green Revolution" has had an impact in some areas of the world, but the effect has been to slow rather than to correct diminishing per capita food supplies.

The world food supply is highly variable depending upon environmental stress or pest factors. More and more dependence is being placed on a relatively few agriculturally favored nations to make up for these periodic food shortfalls and the gradually increasing world demand for food and fiber.

Current export demands have contributed to a sizeable increase in domestic food costs. This has happened in spite of above normal production levels in this country. Severely reduced production levels arising from environmental stress or a new strain of an insect or disease could result in a loss of our expanding export markets and cause further increases in domestic food prices.

Survival, trade, and altruistic purposes have a common meeting ground in crop protection. Twice in the last decade, strategic reserves of food and feed grains have been reduced to a low level as we acted to meet the needs of foreign people. The bounty of our fields was the world's reserves. The risk that our fields might fail is implicit in these situations. We believe the occasions will become more frequent when America will be called upon to market or otherwise share massive amounts of food with other nations. It is a responsibility of the appropriate agencies to provide support in assuring and maintaining a position of strength through dependable and adequate supplies of food, feed, and fiber.

Committee Recommendations

IN addition to making general recommendations on methods of achieving effective levels of support, the committee thoroughly analyzed the situations on plant genetic resources, host-pest interactions, monitoring pests, exclusion of foreign pests, and cultural and field practices and made proposals for each of these areas. Because of space limitations, this article omits some of the supporting data for the various proposals. Readers who are interested in reviewing and studying the complete report may request copies from the editorial office of *Review*.

General

PROPOSAL: *The Secretary of Agriculture and the President of the National Association of State Universities and Land Grant Colleges should act promptly to arrange for a National Plant Genetic Resources Commission to assure the proper management of these vital natural resources.* The Commission should be established at the highest possible level to achieve effective levels of program support and coordination among public and private agencies having programs and responsibilities relating to plant genetic resources.

This Commission would assess national needs and identify program alternatives for conserving and utilizing genetic materials and other approaches to reduce the vulnerability of crops and other valuable plant resources. It would exert influence through fund allocations and coordination to insure the availability of genetic material and research required for further improvement and protection of crop species.

Proposal: *Develop a national plan for plant genetic resources and coordinate its implementation.* Areas of emphasis within the plan would include:

1. Program development to assess the scope, quality, and usefulness of genetic resources in order to decrease genetic vulnerability to diseases, pests and other hazards.
2. National surveys of advanced, primitive and wild genetic resources of plants held by institutions and scientists in the United States.
3. Development of a program to assemble, analyze, and retrieve this information.

Proposal: *Collaborate in international efforts to conserve and manage the world's genetic resources.* The United States has developed most of its crop production system around genetic resources obtained from other parts of the world. It has developed numerous germ plasm collections based on foreign plant explorations and exchanges. There has generally been a liberal approach to making materials from these collections available to foreign scientists. This policy must continue. We should freely and vigorously collaborate with all appropriate world organizations in collecting, perpetuating, exchanging, evaluating, and using man's heritage of plant genetic resources.

Plant Genetic Resources

PROPOSAL: *Take steps immediately to salvage the most critically threatened endemic genetic resources of major crops—wheat, rice, barley.*

Proposal: *Put into operation a planned, coordinated, systematic, and comprehensive program of plant exploration and introduction.* We should not risk the possible tragic results of waiting until the next major epidemic strikes before action is taken. The program should seek the broadest possible continuing access to the world's plant genetic resources.

Proposal: *Develop facilities in the tropics adequate for the maintenance and use of plant genetic resources of tropical origin (e.g., corn, cotton, sorghum, beans).*

Proposal: *Expand the mission and increase the operational effectiveness of the National Seed Storage Laboratory at Ft. Collins, Colorado.* Consideration should be given to determining the potential of the Ft. Collins facility for providing a focal point for the national plan for plant genetic resources. Perhaps it should have a new name and an expanded mission! Limitations in staff and support from the beginning of the Laboratory and gradual further reductions leave it in a desperate situation for performing even its originally assigned functions. Stored stocks are being lost because of inadequate resources for replenishing them. Continuation of these losses could have serious national repercussions.

Proposal: *Inventory existing U.S. collection of viable plant genetic resources to determine the general nature and scope of the germ plasm involved, the uniqueness of the collections, and the need and any special requirements for perpetuation.*

Proposal: *Develop germ plasm pools for each of the major crops.* In addition to maintaining individual stocks as practicable, systems should be developed for creating interbreeding germ plasm pools. The pools should serve to increase the usefulness of the germ plasm in breeding programs.

Proposal: *Intensify and expand research on the biological, physical, and chemical aspects of successfully storing and perpetuating plant genetic resources.* Extended life spans and high germinability of seed stocks are essential to effective germ plasm preservation and use. When seed production is difficult, adequate techniques are needed for vegetative

propagation. The options of tissue culture or other means of germ plasm perpetuation need to be understood and implemented where practicable.

Proposal: *Establish a committee of genetic resource experts for each major crop and for groups of crops produced in lesser quantities.* The highest possible expertise is required and the most knowledgeable people available should be appointed to the appropriate committees. It is impossible for a wheat specialist to know very much about rice or maize; nor is it possible for one person to know all about the germ plasm of a single crop.

Proposal: *Carefully review current plant improvement methods and objectives as they relate to genetic vulnerability.* The National Academy of Sciences study documented the present status of genetic vulnerability and provided some insights on how we arrived at this position. Individual scientists, scientific societies, and public and private agencies that employ plant breeders, geneticists, and other disciplines engaged in plant improvement work—all have responsibility for boot strap assessments of what can be done with current technology to alleviate the nation's pattern of genetic vulnerability.

Proposal: *Develop and implement an array of basic and applied research projects directed toward more efficient gene management.* It is not enough just to have an adequate supply of diverse germ plasm. Ways must be available for manipulating and managing such genetic materials and systems to effect and maximize potential gains and to protect advancements already achieved.

Proposal: *Develop improved techniques for evaluating the suitability of basic plant genetic resources for use in plant improvement programs.* Most frequently, specific useful characters or combinations of characters occur in only a small fraction of a population of basic stocks or endemic strains of a species. Ways need to be found to simplify and expedite the identification of characteristics useful for meeting given objectives.

Proposal: *Develop applied methodology for collaborative multiple screening techniques.* The present screening of germ plasm collections is often haphazard, unsystematic, and inefficient.

Proposal: *Determine how the Federal Seed Act and the Plant Variety Protection Act relate to genetic vulnerability.*

Host-Pest Interactions

PROPOSAL: *Markedly increase research to develop a better understanding of the basic nature of host-pest relationships, particularly pest resistance in major crops.* Logic dictates that there are underlying reasons why some pests attack some species of plants and not others. We know, for example, that some plants produce chemicals that repel or inhibit the feeding of insects. Yet we have done little to develop techniques for screening chemicals as a means of identifying insect resistance.

Proposal: *Intensify research to understand the developmental patterns of economic plant pests, including the characteristics and conditions that result in epidemics.* The vulnerability of crops is largely a matter of vulnerability to pests because of genetic uniformity in the plants; that is, a reservoir of uniformly susceptible host for the pest to attack. The extent to which we understand pests and pest populations enough to control them is closely related to the extent to which the uniformity aspect of genetic vulnerability is significant.

Proposal: *Develop better pest management programs.*

Proposal: *Evaluate the importance of genetic diversity as a tool in pest management.* The concept of pest management is founded on applying knowledge about pest, parasite, predator, competitor, and host plant life histories. The potential contribution of genetic diversity to effective pest management needs to be better understood.

Proposal: *Develop better means for laboratory rearing of pests and for screening host plants for resistance.* Crop varieties need to be as thoroughly evaluated as possible for their responses to pests before they are released for commercial growing.

Monitoring Pests

PROPOSAL: *Continue and expand the cooperative economic insect survey.* A cropping picture involving a common genetic base distributed over a large area makes an early warning system for insect buildups essential. The survey should be adequately supported in the 29 States that now have a survey entomologist. It should be extended to include all other States.

Proposal: *Continue and expand programs for the detection and dissemination of information about*

the nature and occurrence of plant diseases. Continue the nationwide cereal stem rust survey and take into account any other continuing monitoring of pathogens.

Proposal: *Develop predictive models of pest population outbreaks.* Insect and disease surveys will be markedly enhanced if we are able to identify signs and conditions that allow for accurate predictions of things to come.

Proposal: *Continue to develop and refine means of early detection of changes in pest virulence on crop varieties as well as shifts in the varietal picture.*

Exclusion of Foreign Pests

PROPOSAL: *Support research on pests in foreign lands through Public Law 480 projects and grants to foreign research organizations and through overseas research programs of USDA, FAO, foundations, and others.* Studies should identify foreign pests potentially hazardous if introduced into the United States.

Proposal: *Establish a facility off the U.S. shores for studying exotic pests.* Exotic pests with the greatest potential for damage to U.S. crops should be studied in U.S. facilities sufficiently removed from our shores to insure that the pests will not escape to the mainland.

Environmental Stresses

PROPOSAL: *Intensify research on the relationships of crops to water, temperature, salinity, nutrient, pollutant, and other environmental stresses.* Environmental stresses on crop plants are a fact of life that we must face as we seek knowledge and technology for meeting our basic needs for sustenance. History tells us, for example, that sustained, debilitating drought will occur again over major parts of our most important crop production areas. Air pollution is limiting crop production in some areas. Widespread culture of genetically similar varieties may result in greater losses from environmental stresses than would otherwise be the case, particularly if the varieties have not been selected for stress tolerance. We must have better understanding of differences among strains and varieties in their ability to withstand stresses, and of the alternatives that are available for continuing to produce adequate supplies of food, feed, and fiber in situations of extreme environmental stress.

Cultural and Field Practices

PROPOSAL: *Study the extent and effects of spatial and temporal monoculture practiced in the production of major crops as related to genetic vulnerability.* A significant part of genetic vulnerability is the growing of a crop variety or varieties with a common genetic base over large or contiguous geographic areas. We need to know much more about the manner and extent to which our cropping practices contribute to genetic vulnerability.

Proposal: *Support research and systems analyses directed toward an understanding of (a) the interactions that occur between the crop and pest populations with different spatial and temporal cropping patterns and scales of agricultural enterprise, (b) the effects of these interactions on the development*

of effective pest management systems, and (c) trade-offs among alternative management strategies such as crop rotation, plant density, double cropping, levels of tillage, pest resistance, increased genetic diversity, pesticides, parasites and predators, trap crops, insect pathogens, genetic manipulation of pests, etc.

Proposal: *Study methods of encouraging greater crop diversity.*

Proposal: *Inform farmers, seedsmen, plant breeders, and others of any advantages of spatial and genetic diversity in reducing the vulnerability of crops.* An educational program should be mounted to provide all of the facts so that the nation may respond to the genetic vulnerability question in an orderly and methodical way.

ALFALFA PROTEIN FOR HUMAN USE

ALFAFA may assume a new role as a possible food fortifier. Unlikely as it may seem, taste tests of alfalfa-fortified snacks scored well in University of Nebraska experiments.

The basic method for producing a protein concentrate from alfalfa consists of grinding the leaves and pressing the juice from the fiber. The liquid can then be separated into a green protein coagulate plus a clear, brownish high protein solution. The high protein solution is then used to prepare a dry, tan protein concentrate that has possible uses as fortifier.

Researchers L. D. Satterlee, J. G. Kendrick, and Kathy J. Liska then had to find a combination of concentrated plant protein and traditional grain protein sources that would give a high protein flour with an essential amino acid profile better than the profile available from any single plant protein.

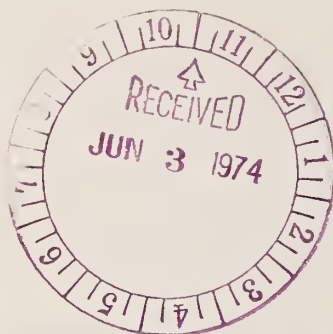
They formulated a high protein flour utilizing alfalfa protein, soybeans, dried potato, and glandless cottonseed protein isolate. The essential amino acid profile of the mixture exceeded that of soy protein, which is assumed to be the most nutritious of the plant proteins.

High protein food snacks were produced using the high protein flour mixed with cornmeal and water. The fortified cornmeal was formed into a small, puffed product called a collet. Dried collets were flavored with a cheese coating made from powdered cheese, salt, and oil.

Thirteen types of snacks of varying protein concentrates (soybean protein and high protein flour at differing levels) were evaluated by a 12-member panel for appearance, aroma, texture, and flavor.

The soy snacks fared best in the testing. They exceeded the excellent rating, even with a 36-percent protein content and were as acceptable as the marketed cornmeal snack used as a control.

However, the corn snacks fortified with the high protein flour (containing alfalfa protein isolate) were also acceptable to the panel at levels of fortification up to 20 percent protein. Current research is being directed towards refining the process of isolation to yield a 73-percent protein concentrate. Further decolorization and deodorization is expected to produce an isolate that will fully compete with soy protein as a fortifier in the human food marketplace.



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